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OPERATIONAL GUIDELINES FOR URBAN COMMUNICATIONS(U)
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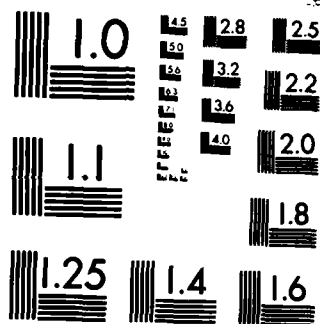
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DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
WASHINGTON, D.C. 20380

IN REPLY REFER TO

RD/CCT
SCN: 60-81-03
18 JAN 1985

From: Commandant of the Marine Corps

Subj: OPERATIONAL GUIDELINES FOR URBAN COMMUNICATIONS STUDY

1. The objectives of the study were:

a. The identification of communication requirements applicable to Marine Corps operations in built-up areas (MOBA).

b. The development of an appropriate set of characteristic data and analysis tools to systematically dissect these requirements and to determine the best strategy for minimizing the effects of the urban environment upon communications.

c. The translation of the strategy into recommendations, working tools and methods which can be applied by deployed forces in the MOBA environment to eliminate communication deficiencies.

2. The objectives were met by this study and the format of the study gives planning data and suggestions for improvement of tactical communications in an urban environment.

3. The results of the study are concurred in.

4. A copy of this letter will be affixed inside the front cover of each copy of the subject study report prior to its distribution.

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EXECUTIVE SUMMARY

This report is a revised version of "Tactical Communication Techniques in Urban Environments," 23 Sep 1983, with the objective of focusing on training, education and background issues of urban communications.

This summary of the previous report is on the following page. The summary of this report is on page 7-1.

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TACTICAL COMMUNICATIONS TECHNIQUES

EXECUTIVE SUMMARY

1. Urban area communications difficulties arise from: (a) large direct path signal losses, (b) multipath interference, (c) high urban area noise/interference levels, and (d) tactical radio antenna system inefficiencies.
2. The statistically independent nature of urban communication paths over small changes in frequency and antenna position should be exploited by operators. The result will be improved communications equal to or better than the technical improvements discussed in this report.
3. Netted communications structures with automatic retransmission should be implemented, when necessary, to bypass the statistically poor paths. Future systems have incorporated automated relays for this reason (Packet Radio, PLRS, Cellular Radio).
4. Selection of frequency band(s) for urban communications is difficult. Propagation is least affected by urban structures in the lowest frequency ranges; however, efficiency of practical tactical antennas is also very low in these ranges (HF, VHF). Improved HF and VHF antenna efficiencies and improved radiation locations can be simply accomplished by the acquisition and training in the use of reel or reel-type antennas.
5. Wire communications should be more fully utilized. Future fiber optics communications will provide greater bandwidths and will be far easier to deploy than the current wireline methods.
6. The new VHF radio, SINCGARS, will, in the frequency hopping mode, statistically average out multipath effects and may produce improved urban voice communications.
7. PLRS, with its automated relay capability, may be well suited to the urban problem and initial testing should include urban environments.

8. Power-line coupling and ultraviolet radio should be further investigated for use in intrabuilding and local area interbuilding applications.
9. Commercial developments, such as those used with paging devices, should be evaluated in depth, and possibly acquired.

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SECTION 1
INTRODUCTION

The Reason To Be Concerned

1.1 BACKGROUND

Growing Population Centers

Rapidly increasing population growth and the world political environment has heightened the chances of military operations in urban areas. The Marine Corps, in keeping with its "force in readiness" concept, must be prepared for operations in these built-up areas. Urban operations introduce significant constraints and unusual conditions which must be addressed both during communications planning evolutions prior to arriving in the operating area and during urban area operations.

Urban Induced Problems

Instead of rolling hills and forestation, typical in field training exercises, urban areas are characterized by streets, bridges, buildings and a host of man-made objects which affect communications in a variety of ways. In the urban environment ground based communications are distinguished by a combination of (1) large direct-path signal losses, (2) multipath reflections and (3) proximity effects on antenna patterns caused by nearby structures. The urban environment hits the radioman with the worst of each of these effects. The direct (line-of-sight) signal path may be heavily absorbed, leaving communications primarily to random multipath effects and further confused by disturbed antenna patterns. In addition, the urban communicator is faced with high urban noise levels and is usually restricted to using inefficient antennas (physically too short), at the wrong locations (street level instead of building top or hilltop levels). While today's landing force may have grown accustomed to available and reliable communications over many kilometers with a field radio, this same radio might not reach out two city blocks in an urban area.

1.2 PURPOSE

Be Persistent

The purpose of this document is to identify the characteristics of the urban environment which influence communications by operating forces. Measures to overcome the problems to be encountered in the urban terrain are outlined and discussed. Techniques which will assist communications planners and equipment operators are provided along with guidelines which can serve to improve present capabilities and performance. The most important message of this handbook is that you must not give up! With a little knowledge and thought, many obstacles can be overcome. In some cases, the very object which appears to be an obstacle can become an enhancement, if used properly.

1.3 GENERAL REQUIREMENTS

Urban Area Characteristics

The conduct of operations into a major urban complex will impose communication problems on the landing force that it would not normally face in more open terrain. The most salient problem is the uniqueness of urban areas. The significant urban factors are the structural profile of the urban areas and the electromagnetic interference environment. Buildings and other structures inhibit line-of-sight radio communications by absorbing and reflecting transmitted signals. Concurrently, existing commercial and military radio frequency (RF) sources are competing for the use of available frequencies. Also, urban noise levels from motors, generators, ignition systems, power lines and other similar electromagnetic emitters provide RF interference. The use of in-place communications capabilities that may exist in the urban areas is one of the few benefits which derives from operations in the urban environment.

Unique Requirements

Urban operations demand an assortment of physical communication capabilities, to include street to street, street to building, street to air, building to air, interbuilding and intrabuilding. A wide spectrum of building interiors and exteriors (including rooftops), and units maneuvering on city streets must be considered when addressing urban operations. Communication techniques must satisfy short (i.e., hundreds of meters) and long (i.e., several kilometers) range transmissions, generally under conditions of

limited or non-existent line-of-sight. Finally, usual considerations of communication security, quality, and reliability are equally applicable to urban operations as they are in the field.

1.4 OPERATIONAL REQUIREMENTS

Most Difficult Situation

The most demanding situation, in terms of communications requirements, that may be faced by a Marine Air-Ground Task Force (MAGTF) would be an amphibious assault by a Marine Amphibious Force (MAF) into a major urban complex. This situation could involve a complete cross section of urban structural characteristics and elements of the urban electromagnetic environment; a substantial enemy threat, that includes the employment of Radio Electronic Combat and its hostile electromagnetic environment; the full range of amphibious operations that involve all four elements of the MAGTF (command element, ground combat element, aviation element, and combat service support element); and extended subsequent operations ashore.

Multiple Circuits

Communication nets are established to satisfy communication requirements of the landing force during an amphibious operation and subsequent operations ashore. In addition, depending on the command relationships established for an operation, MAGTF headquarters may require nets with the Unified Command, Joint Task Forces, other U.S. services, allied military forces and perhaps civilian agencies either inside or outside the objective area.

Net Utilization

Communication nets are established to provide for the continuous capability to command assigned forces; to control and coordinate movement of combat forces, supporting forces, and logistics; and to collect and disseminate information. Communication requirements range from the division headquarters down to the squad, team, and tactical vehicle level, with the nets as defined in FMFM 10-1.

Air Control Nets

Air wing communication nets are for the various air control system agencies. The tactical communication system, in addition to being responsive to the command and control needs of the wing, is adaptable for integration and operation with the naval communication system normally employed in amphibious operations and parallel the command echelons of the ground component. The nets are established in accordance with NWP 16 and FMFM 10-1.

Combat Support Nets/Combat Service Support Nets.

In providing support to the various elements of the MAGTF, combat service support must have a flexible and responsive communication system. The functional support areas include military police, maintenance, supply, engineering, motor transport, medical, dental, landing support, and naval construction. The appropriate nets are described in FMFM 10-1.

1.5 SPECIFIC REQUIREMENTS

Demanding Conditions

While all elements and echelons of the MAGTF will have unique communication requirements due to the urban environment, the most demanding are those involving combat operations, reconnaissance and surveillance. Urban communications requirements will include the following forces and units.

Building-To-Building Operations

When the smaller infantry units (battalion down to squad) commence combat operations within buildings, they will run into serious control and coordination problems, since the elements of the unit lose visual and vocal contact with each other. This can be a three-dimensional problem, with units spread laterally within a building (or buildings) and vertically from rooftops to subterranean levels. Visual techniques, such as hand signals and signs, provide a partial but very limited solution for smaller buildings, but there is a definite need for radio communications to provide a responsive command and control capability for infantry combat operations in a major urban complex.

Tank Units

Tank/infantry/engineer/self-propelled artillery task forces will be conducting combat operations within the streets. In large cities such operations will be similar to operating in deep narrow canyons. The various elements of these task forces may be operating on parallel streets, but with no visual contact. Similarly, tank units will be coordinating their advance with that of infantry units operating inside buildings. There is a need for radio communications to be established between the elements of tank units and between tank units in the streets and infantry units inside the buildings.

Fire Support

Both the infantry and tank units will require fire support from artillery and mortars. In locating suitable firing sites, the artillery and mortar units may be at long distances from the supported units with build-up areas that preclude line-of-sight communications. In order to request and adjust fires, the infantry and tank units require responsive communications with the artillery and mortar units.

Close Air Support

Air defenses will frequently force friendly fixed and rotary wing aircraft to fly at low altitudes, seeking to mask themselves from detection and attack. However, these low-level tactics will also create line-of-sight problems with infantry and tank units that are requesting close air support or assault support. The forward air controllers may not establish line-of-sight contact with the supporting aircraft until it is on scene, and even then may lose line-of-sight contact with the aircraft as it maneuvers to carry out its mission. This problem will occur primarily along the forward edge of the battle area (FEBA) where the friendly units may not have sufficient control of rooftops to permit effective siting of forward air control facilities.

Air Defense

Elements of the Forward Area Air Defense (FAAD) battery will accompany infantry and armor units to provide them with an air defense capability. In the urban environment it may be difficult to simultaneously find a FAAD location that provides forward fields of vision for fire and rearward unobstructed communications.

The FAAD elements may be at an extended distance from the Direct Air Support Center or be out of line-of-sight with a tactical air control facility that is situated inside an adjacent building.

Intelligence and surveillance

The cover and concealment provided to the enemy by the urban environment will greatly reduce the effectiveness of most reconnaissance and surveillance operations. Accordingly, the use of reconnaissance teams and remote sensors may take on increased significance, even though the urban environment will decrease their effectiveness. These teams and sensors will probably be operating at extended distances, and thus out of line-of-sight contact with friendly forces. In order to be able to report time sensitive intelligence information to headquarters, responsive communication link will be required.

SECTION 2

CHARACTERISTICS OF URBAN RF ENVIRONMENT

What It's Like In The City

2.1 PROPAGATION PHENOMENA

Urban communications difficulties introduce many complications into the conduct of combat operations. Assuming that effective communications are essential to success of urban operations, it is important to recognize specific constraints and unique features of the urban RF environment which affect communications. Among these characteristics are the phenomena of multipath signal, proximity effects, direct path loss, degraded antenna efficiencies, interference caused by noise and other RF users and the importance of frequency management. The effects of these phenomena will never be clearly separable. Operators will see only the sum total of all these effects.

2.2 MULTIPATH AND DIRECT PATH LOSS

Absorption and Reflection

A two dimensional view of the urban communication problem is illustrated in figure 2-1. Additional paths and path links between antennas A and B will result from reflections from off-path objects. The direct path between A and B suffers from absorption and reflection of the signal by intervening buildings. The signal loss may be so great that direct path range is severely limited. Numerous alternative paths exist as a result of off-path reflections from buildings, nearby hills, aircraft and so on.

Multipath Peculiarities

In any urban situation it is virtually impossible to predict which, if any, of the paths will produce the strongest signal. In most cases, due to direct path losses and presence of numerous possible alternative paths, the resulting received signal is a combination of a number of paths (called multipath). Multipath and severe direct path signal losses are the prime

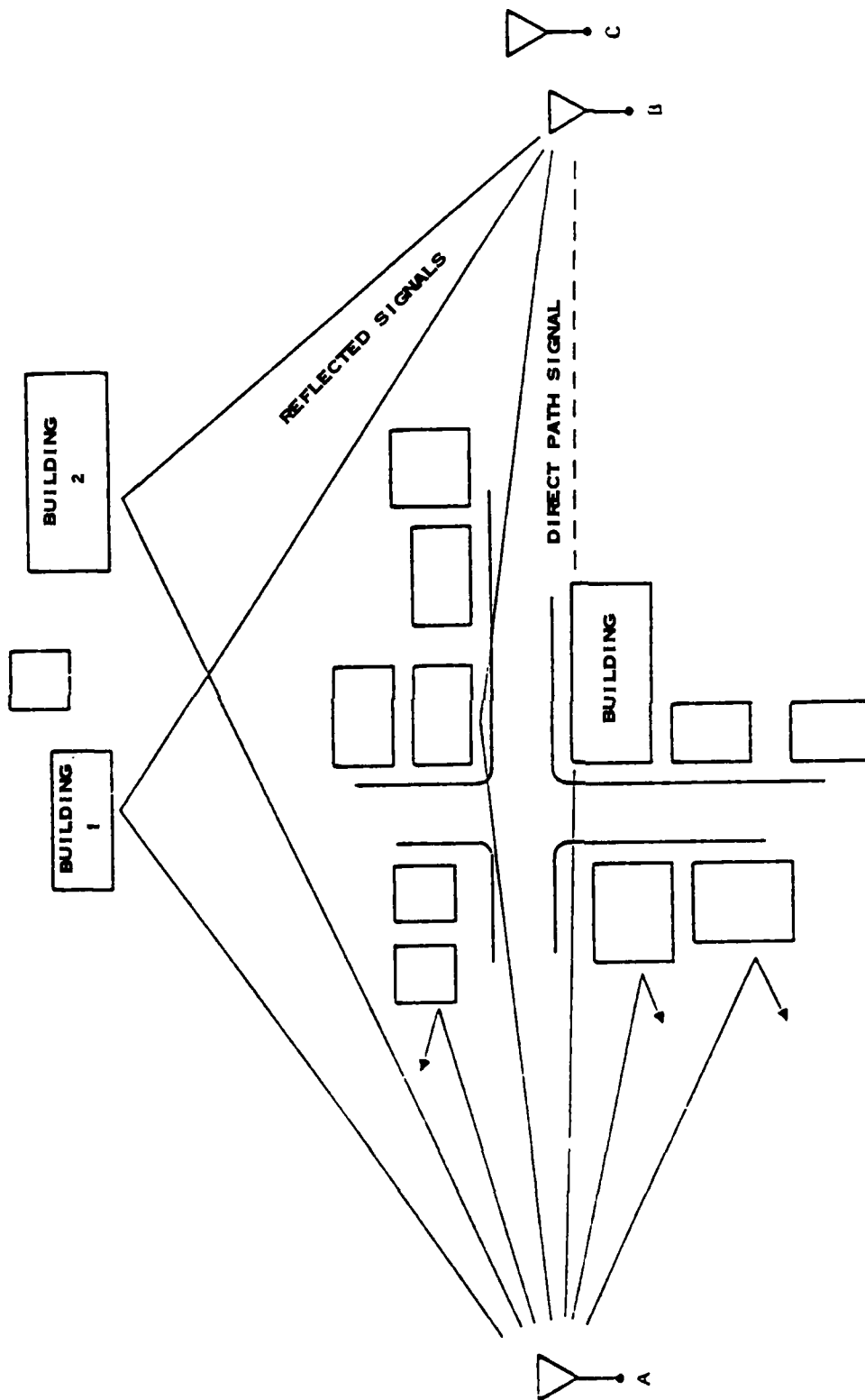


Figure 2-1. Typical Urban Communication Paths

characteristics of urban communications. Multipath deserves serious consideration because signals from various paths usually arrive at the receiving antenna out-of-phase with each other resulting in phase cancellation or multipath interference cancellation. In the case of two equal strength multipaths with the signals arriving out-of-phase with each other, the received signal will be zero! It is also possible that they will arrive in phase and result in signal addition. The resulting signal strength is critically dependent upon position. If the antenna at position B on figure 2-1 is moved $\frac{1}{2}$ wavelength to position C (about 20 feet at mid-VHF band), the phase relationships between arriving paths will be completely different and signal strength is often observed to change by 5 to 20 dB. This change may be either positive or negative.

Frequency vs. Multipath

Multipath influence dominates as frequencies increase. At the lowest HF radio frequency of 2 MHz the wavelength is 150 meters (500 feet) long and most buildings and obstacles only minimally affect the signal. As frequencies increase, the shorter wavelength signals are more likely to be reflected. Because multipath is different for different parts of the radio frequency spectrum, three divisions are made and examined below.

2.2.1 MF-HF (300 kHz - 30 MHz)

Multipath is not usually a serious source of degradation for this portion of the spectrum. The wavelengths are relatively long, one kilometer to 10 meters (3,279 feet to 33 feet) and consist of groundwaves and skywaves. Groundwaves penetrate most urban and suburban structures and undergo attenuation from this penetration. The skywave is often characterized by fading and its attendant distortion. Skywave is generally not considered in local area urban communications because of low transmitter powers and inefficient antennas for near vertical overhead links. However, in many cases (especially on circuits over 10 km) HF skywave may be the only viable technique.

2.2.2 VHF-UHF (30 MHz - 3 GHz)

Performance may be seriously degraded due to multipath in the urban terrain. The VHF and UHF bands are employed in tactical situations because acceptable performance is possible with relatively low power and modest size requirements for antennas. The wavelengths are 10 meters to 10 centimeters (33 feet to 4 inches) in size. Degradation occurs because the wavelengths are comparable to the electrical sizes of the urban structures which permits

significant reflection, refraction and attenuation of the signal. The attendant distortion and/or reduction of signal strength can vary significantly with transmitter and/or receiver placement with 10-20 dB variation over a few meters being common. At the higher frequencies of UHF, building penetration by the signal may be possible.

2.2.3 SHF-EHF-Millimeter Waves (3 GHz - 3,000 GHz)

An SHF system (AN/TRC-170) being developed for operation after 1987 will be used in line-of-sight (LOS) installations in the urban terrain or in a troposcatter transmission mode. The shorter wavelength EHF system (Single Channel Objective Tactical Terminal, SCOTT) is to be a satellite system for operations after 1989. Multipath caused by urban terrain should not be an important consideration for these systems because it is already known that their performance will be limited to line-of-sight applications in built-up areas; therefore, their use below rooftop level is not planned or recommended in the urban terrain.

2.2.4 Digital Multipath Considerations

Digital Signals

Use of digital signals can lead to another complexity beyond the multipath phase cancellation already discussed. The data bits arriving over different propagation paths can interfere with each other. It is accepted from empirical evidence that multipath begins to seriously degrade digital performance when the multipath signal arrives at the receiver approximately 10% or more of the bit length later in time than the direct signal as shown on figure 2-2. An additional condition is that the strength of the multipath signal generally must be within 10dB of the direct signal to cause problems. If either or both of these conditions do not occur, the receiver usually locks onto the stronger signal. However, both conditions are very likely to occur in the urban environment. For a 16 kbps modulation rate, the bit length is 62.5 μ sec. Thus, when the time difference between the direct and multipath signal is about 6.25 μ sec or more, multipath interference will degrade the digital signal as shown in figure 2-2. The effect is called intersymbol interference.

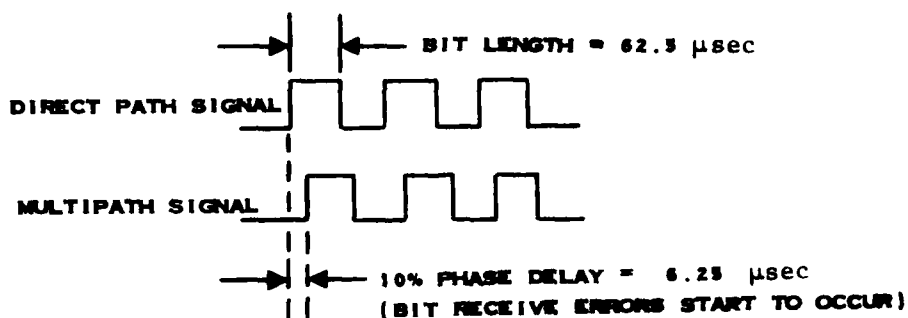


Figure 2-2. Multipath Phase Delay

Path length

Assuming that the propagation velocity is the speed of light, the difference in path length of a multipath signal which can adversely affect (10% phase delay or greater) the performance of a direct path 16 kilobaud signal is:

$$3 \times 10^5 \text{ km/sec} \times 6.25 \times 10^{-6} \text{ sec} \geq 2 \text{ km}$$

Tactical test results have shown that the nominal digital transmission range at which a low error rate can be attained is between 7 and 10 km. For a direct path of 10 km, the length of the multipath circuit thus must be about 12 km or greater to cause problems. Figure 2-3 illustrates typical multipath geometry. Multipath A reflected from a building close to the azimuth of the direct path (grazing reflection angle) will not cause a problem because the difference in path length is less than 2 km even though there is little reflection loss. Multipath B from an overhead aircraft can lead to degraded performance. The aircraft multipath problem is the most severe because that path does not have the groundwave path loss of the direct signal and, in addition, the reflection loss from the metallic surface is low. Multipath C to a distant building or hill may have little effect because of the loss of energy (large reflection angle loss by the structure) and the long path (14 km). In general, the received multipath signal strength will typically be less than direct because of (1) longer path lengths and (2) reflection point losses. However, in an urban environment the direct path loss may be large and multipath signals are often the strongest component.

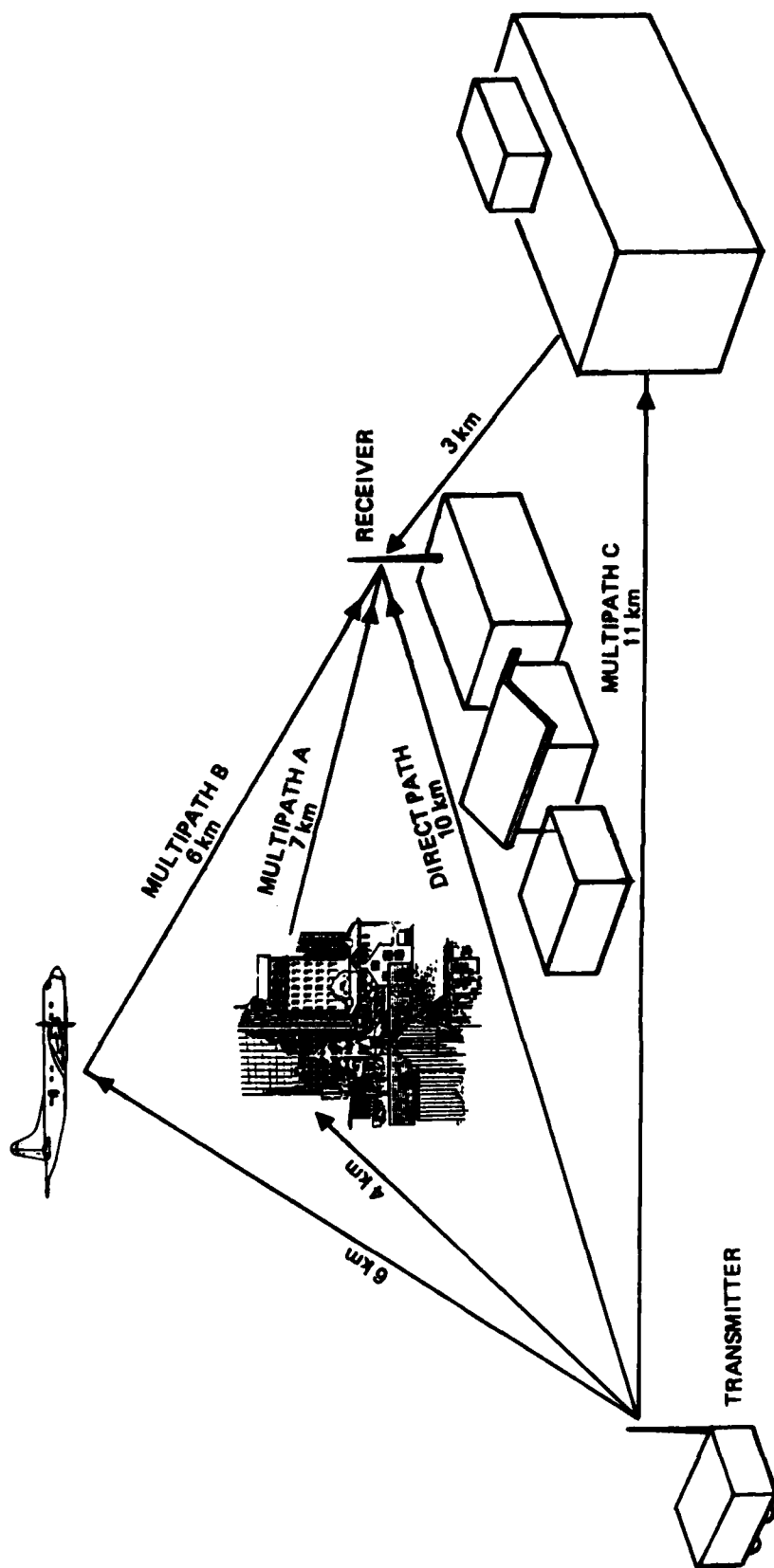


Figure 2-3. Illustration of Multipath Geometry

The preceding argument suggests that for a reflecting object to be a problem, it must be outside but close to the perimeter of an ellipse with the transmitter and receiver at the foci (locus of points providing a constant multipath length). It also must not be too far away and it must have a high reflection coefficient at the angle of incidence or the multipath signal strength may drop more than 10 dB. At transmission ranges of 10 km and less, the number of fixed points of reflection meeting the above criteria are few. At longer ranges, multipath is a significant consideration, however within the limited useful range of tactical ground digital VHF communication equipment, the geometry is generally unfavorable for the presence of significant intersymbol interference of digital signals. A major exception is, of course, aircraft multipath.

Cumulative Effects - Urban Environment Example

In the urban environment, the influences of multipath variations, absorption of direct path signal and variations due to proximity effects are intermingled. This is shown on figure 2-4 as these various effects have degrading influences on a VHF signal as the range increases. The data was collected in an area of moderate density, two story buildings of frame or masonry construction in rolling terrain with 30 foot hills.

2.3 ANTENNA EFFICIENCY

The classic definition of antenna efficiency involves the ratio of maximum effective area of the antenna to the aperture area. For wire antennas the efficiency is proportional to the ratio of antenna length to operating frequency. This definition is perhaps more meaningful to design engineers than to an operator. From an operational perspective, it is useful to consider the "antenna system efficiency" where the system includes connectors, transmission line, and any other item external to the transceivers, in addition to the antenna itself. Therefore the coupling of the transceiver to the antenna is an important element. Also, the directivity of the antenna and effectiveness of this antenna system is a function of its elevation and position relative to the urban terrain and nearby objects. This is because these nearby objects become a part of the system by reflecting and radiating or absorbing signal energy. From a distance, the signal emanating from the general area of the transmitting antenna cannot be differentiated by its component sources,

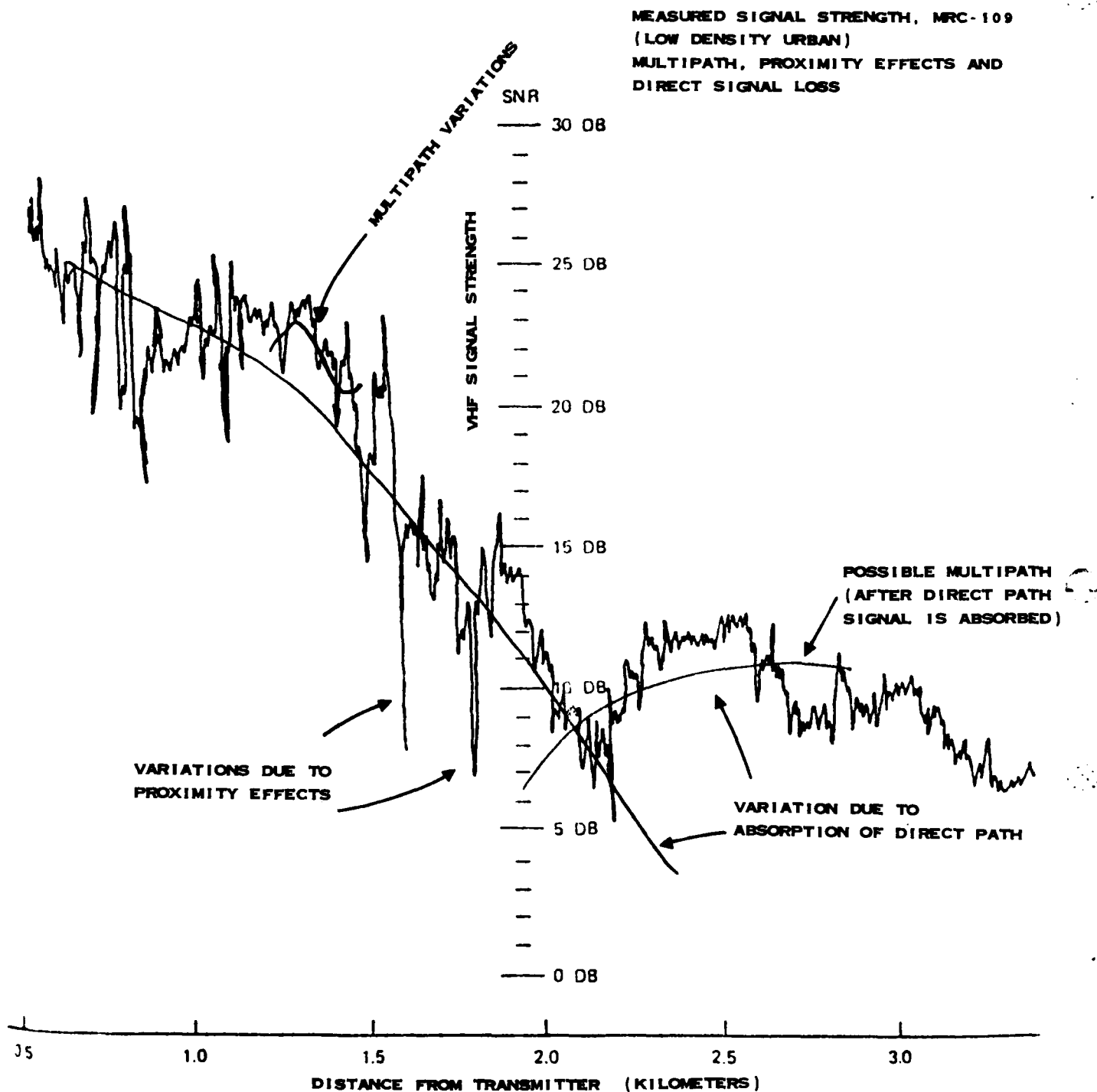


Figure 2-4. Multipath, Direct Path and Proximity Effects

i.e., that portion reflected from a nearby metallic object versus that portion emanating from the antenna itself. Thus, the operator must consider that, in effect, his antenna and its local environment are one large antenna system. It is actually possible to capitalize on this phenomenon, as discussed later in paragraph 4.3.

Certain physical limitations must be considered since HF radio antennas are larger than antennas of higher frequency radios. While HF propagation losses are lower than VHF radios, antenna efficiency is also lower and the relative merits of HF vs. VHF band selection becomes unclear. A general rule of thumb is applied to VHF/UHF radio antenna height relative to range capability. The range approximately varies with antenna elevation, therefore, if antenna height is doubled and all other factors remain unchanged, the radio's range approximately doubles.

Both range and signal quality are influenced by antenna efficiency since reduction of antenna efficiency will result in shortened range coverage. Antenna efficiency is lowest at HF, therefore, greater reductions in signal quality and range coverage are caused at these lower frequencies as compared with VHF/UHF.

Wavelength much different than antenna size

Primary HF radios, such as PRC-47 and its replacements PRC-104 and PRC-105, operate from 2 to 29.999 MHz. Wavelengths can range from 150 meters (488 feet) down to 10 meters (33 feet). At this higher frequency, the wavelength is four times as long as the standard 2.4 meters (8 feet) tactical whip antenna. At the lower end of the frequency range, the wavelength is 61 times as long as the 2.4 meter (8 feet) whip antenna. This large difference in wavelength to antenna size makes it difficult to efficiently couple and radiate at HF. Figure 2-5 shows typical HF wavelengths.

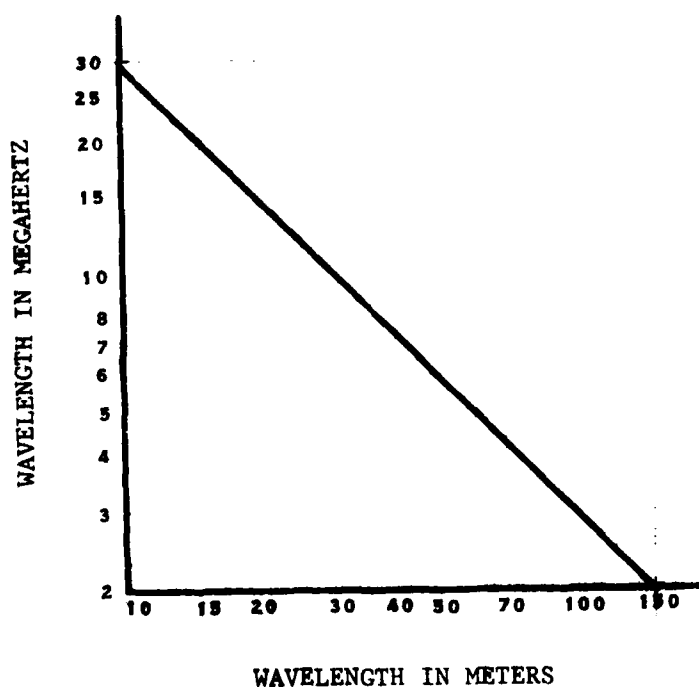


Figure 2-5. HF Wavelength

Wavelength similar to antenna in size

Typical VHF radios, such as the GRC-125 and its replacement, the GRC-160, operate between 30 to 79.95 MHz. Wavelengths can range from 10 meters (33 feet) down to 3.8 meters (12 feet). At these frequencies, the wavelengths are similar in size to surrounding man-made objects such as buildings, tanks, train cars, etc., permitting significant reflection, refraction or attenuation of the signal. Figure 2-6 displays typical VHF wavelengths. VHF tactical antennas are generally efficient since the size, relative to the wavelength is close.

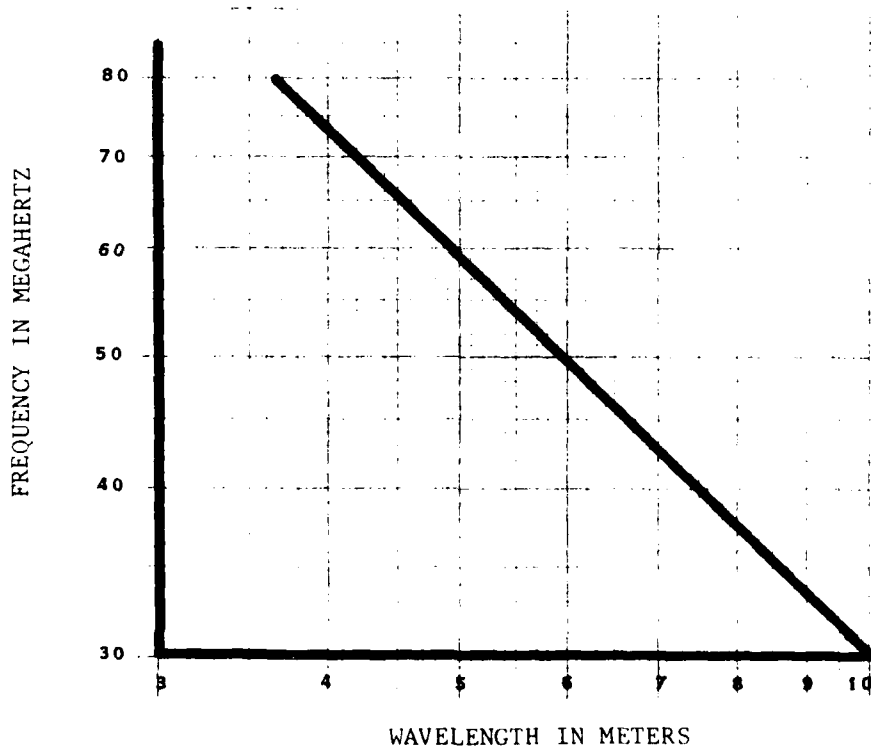


Figure 2-6. VHF Wavelengths

High Antenna Efficiency

Typical UHF radios, such as the PRC-41A and PRC-75, operate between 225 to 399.95 MHz. Wavelengths at these frequencies range from 1.3 meters (4 feet) down to .75 meters (2½ feet). Communications at these wavelengths are largely limited to near line-of-sight; however, antenna efficiency is high since available antennas are frequently half-wavelength in size. Figure 2-7 displays wavelengths at this selected bandwidth.

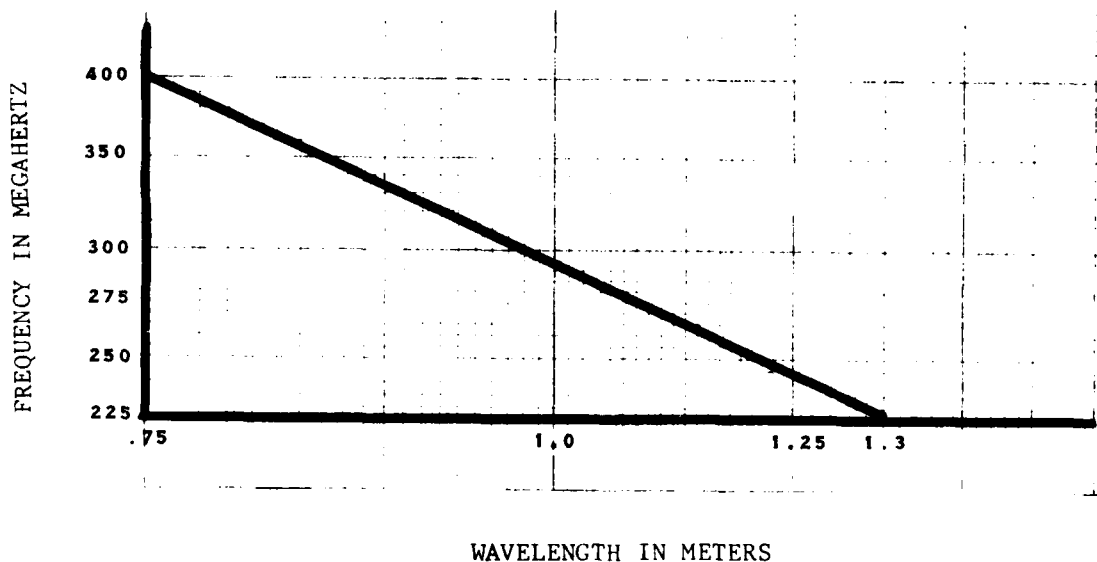


Figure 2-7. UHF Wavelengths

Power Reduction with Frequency Mismatch

The AN/PRC-77 is a man-pack receiver-transmitter that covers the frequency range of 30.00 MHz to 75.95 MHz in 50 kHz increments. Nominal power output is 2 watts, but the actual output power depends on the frequency used, the antenna impedance at each frequency, and other factors. As an example, during testing the output power changed from 2.6 to .9 watts over a frequency range of 39.1 MHz to 42.1 MHz.

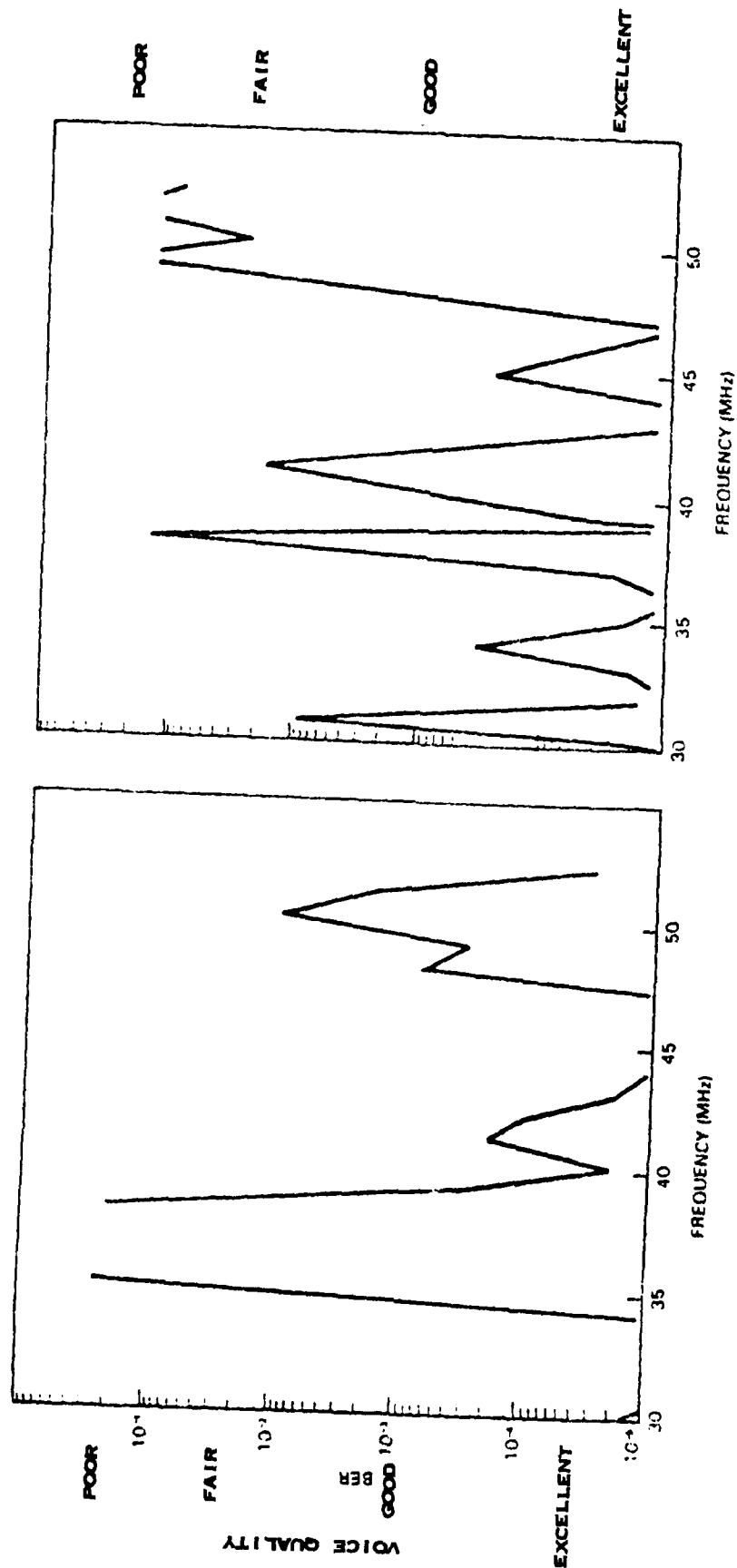
Antenna Configurations

One of two different antennas are normally used with the PRC-77. These are 2.4 meter (8 feet) whip and a .6 meter (2 feet) whip. The longer whip is most suitable for static positions while the shorter whip is most suitable for situations where a high degree of mobility is required.

Tests reveal that changes in transmitter antenna or antenna configuration, keeping all other parameters fixed, caused significant variations in performance. The performance was a measure of error rate and signal strength versus frequency for the PRC-77 transmitter using a 2.4 meter whip and a 1.1 meter (3½ feet) antenna. Variations of bit error rate (BER) from less than 10^{-5} to greater than 10^{-1} occurred over a frequency range of 30 to 52 MHz for the 2.4 meter whip. Over the same frequency range, the 1.1 meter whip had variations in BER from just under 10^{-3} to higher than 10^{-1} . The profiles by frequency are entirely different. For example, a BER of 10^{-5} is observed at 45 MHz for the 2.4 meter whip while BER of 10^{-1} is observed at the same frequency for the 1.1 feet whip. Thus, a change of antenna or transmission line can often make the difference between unacceptable and acceptable performance.

Figure 2-8 shows a similar comparison for a change in antenna configuration. In this comparison a 2.4 meter whip is used in both cases. However, in figure 2-8 (a), the antenna is connected directly to the transmitter while in figure (b), 30 meters (100 feet) of coaxial cable is used and the antenna is located 23 meters from the previous site. The huge changes in performance are typically characteristic of antenna coupling and positioning effects.

The PRC-77 transmitter has no provision for operator adjustment of impedance matching between the power amplifier and the antenna transmission line. Thus, changing the antenna location and/or coaxial cable length can degrade or improve performance at any frequency. Also, note significant changes in signal quality by changes of only a few megahertz of the signal. Enhanced



a. PRC-77, 2.4 meter whip.

b. PRC-77, 2.4 meter whip,
antenna relocated 75',
with 100 ft. coaxial
cable.

Figure 2-8. Quality Versus Frequency for Two Antenna Configurations and Locations

signal strength will be found only by trial and error. If unsatisfactory or marginal communications exist, change frequency and/or antenna position by a small amount. Frequently improvement will result (see figure 2-8 as an example).

2.4 NOISE INTERFERENCE

Radio noise which will affect urban communications is derived from three sources which are external to the transmitting and receiving equipment. These are atmospheric, galactic, and man-made noise. Figure 2-9 displays relative measured values in Washington, D.C. area of urban man-made radio noise, atmospheric noise and galactic radio noise. It can be seen that urban noise is approximately 25 dB above rural noise and is more or less independent of frequency. In the VHF band, atmospheric noise is fairly low and decreases with increasing frequency. Sources of noise at VHF are man-made noises, such as ignition systems, diathermy machines and X-ray equipment. In the UHF band, atmospheric and man-made noise is extremely low, with the exception of vehicular ignition pulses. Interference from other users will be common in any of these bands.

2.5 FREQUENCY

Frequency assignments for a specific operation or a block of time are promulgated in the Communication Operation Instruction (COI). The COI amplifies an existing Communication Standing Operating Procedure (COMMSOP) providing current information on networks, circuits, security and other similar details. Peculiarities of operating radios in the urban environment must be recognized when frequency assignments are made in the COI.

Steel Building Effects

In general, studies indicate that VHF frequencies in the range 50-75 MHz are better suited to urban areas because the wavelengths are 4 to 6 meters. This is a compromise of increased distance afforded by lower frequencies and half wavelength antenna matching of commonly available antennas. Depending upon the location of the antennas, even higher frequencies may be necessary. This is true when antennas are inside steel frame or concrete and reinforcing rod buildings which results in creating a shield for electromagnetic waves. An electromagnetic wave window is defined by the metallic rods or frame so that the window dimensions must exceed the wavelength. This means that a

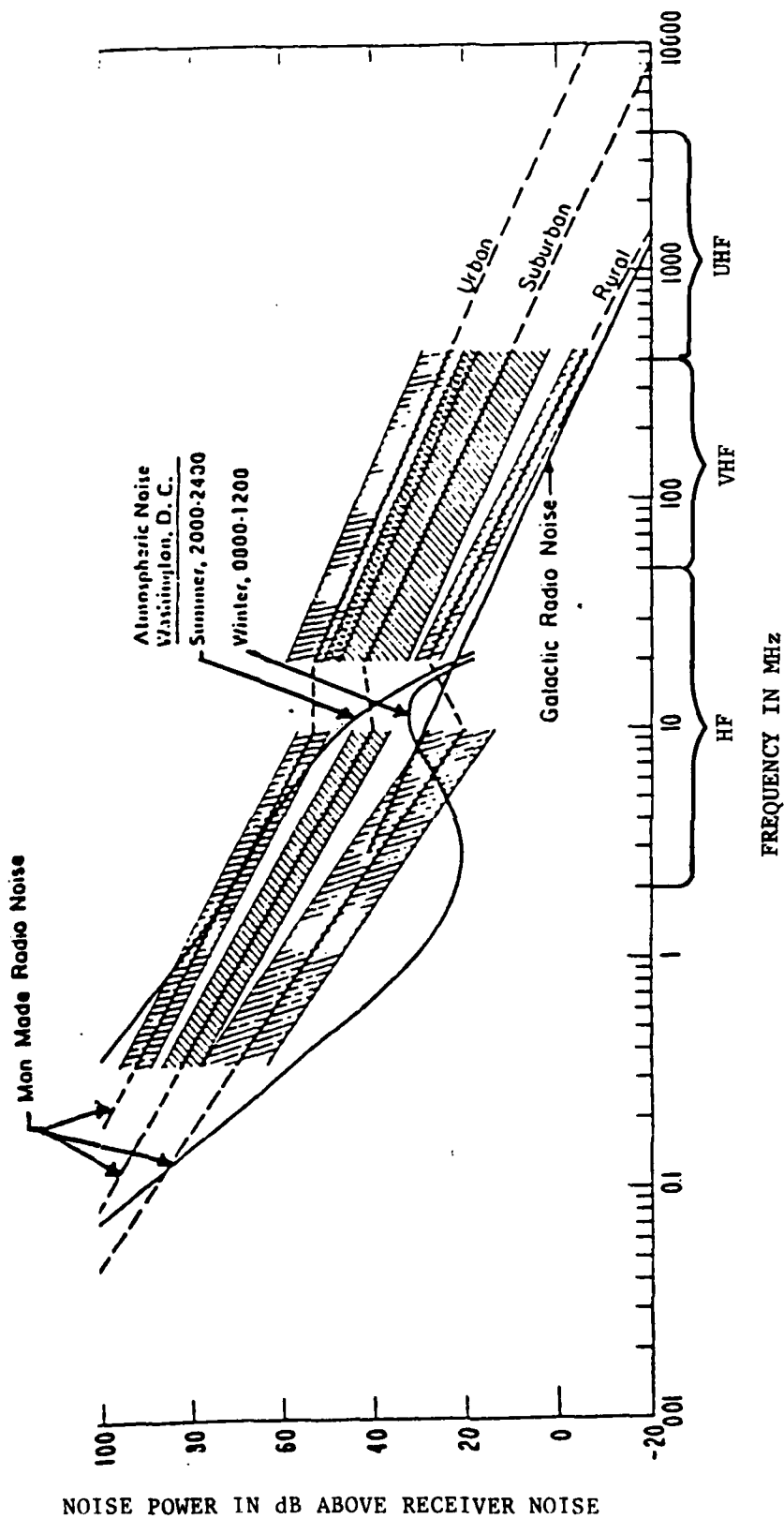


Figure 2-9. Observed Median Values of Radio Noise Power

(from Barghausen, et al. 1969)

steel frame building with steel members seven feet apart will present a propagating window for wavelengths of 2.1 meters (7 feet); therefore, the frequency must be greater than 137 MHz (VHF). To penetrate a reinforced concrete building with rods at 45 centimeters (18 inches) apart requires waves less than 45 centimeters (1½ feet) long which is frequency above 642 MHz (UHF).

Indigenous Spectrum Usage

Frequency management may be complicated in the VHF and UHF bands where sharing the frequency spectrum with host country television, radio, police, fire and other commercial users is necessary. This is particularly true in a peacekeeping operation. The electromagnetic environment consists of both allocated and nonallocated frequency bands. Nonallocated frequencies, called spectrum windows, may contain 2nd and higher order harmonics and intermodulation (IM) products generated by emitters operating within allocated frequency bands. Wherever energy contained within the harmonics and IM products is approximately equal to the thermal noise level at the receiver front end, the spectrum windows may be considered clear and preferred for urban communications utilization. Communication equipment may permit reliable communications within spectrum windows that contain harmonics, or IM products, provided the combined background level of thermal noise, harmonics and IM products is at least 10 dB below the desired signal at the receiver front end.

SECTION 3

CURRENT COMMUNICATION SYSTEMS IN URBAN ENVIRONMENTS

Here's What We Have To Work With

3.1 HF SYSTEMS

In the urban environment, HF systems will perform well for fixed point-to-point communications if antennas are sufficiently large and their locations are carefully selected (see Operator Techniques section).

Principal HF radios are described below.

- AN/PRC-104 and 105 are similar portable HF SSB radios which replaced PRC-47.
- AN/MRC-138 HF SSB is a replacement for MRC-83A with maximum 400 watts and 100 Hz channel spacing. It is mounted on $\frac{1}{2}$ ton M151A2 truck.
- AN/TSC-95 is composed of TRC-171 HF communications central for long-haul data transfer.
- AN/MRC-123 vehicular unit can interface with COMSEC equipment for secure communications. It is mounted on $\frac{1}{2}$ ton M151A2 truck.
- AN/MRC-124 consists of both HF and UHF radios and can interface with COMSEC equipments. It is mounted on $\frac{1}{2}$ ton M151A2 truck.

3.2 VHF SYSTEMS

The mainstay of urban communications is in the VHF range because the antennas are more efficient than HF antennas and building penetration losses are lower at VHF frequencies than at UHF frequencies. The AN/PRC-77 has produced observed typical ranges of 2.4 kilometers (1½ miles) for street-to-street transmission, 2 kilometers (1-1/3 miles) for building-to-street transmission and 120 meters (400 feet) for building-to-building transmission. Principal VHF radios are described below.

- AN/PRC-68 is highly portable, low power, FM transceiver for intra-platoon communications.
- AN/PRC-113 operates in both VHF (116-147 MHz, 2 watts) and UHF (225-400 MHz, 10 watts). A vehicular version is designated AN/VRC-83.
- AN/PRC-77 is the primary portable radio for tactical units in FM, using whip or directional antennas; it replaced the PRC-25.
- AN/VRC-83 is a vehicular version of PRC-113 with higher power and may be fully remoted.
- AN/GRC-125 is a mobile version of AN/PRC-25.
- AN/PRC-25 is a popular low power, short-range, half-duplex FM radio used by units of infantry, armor and artillery.
- AN/GRC-160 will replace AN/GRC-125A. It is low power, short range, half-duplex; either portable or vehicular.
- AN/MRC-135 is a vehicular VHF/FM multichannel analog radio featuring 8 TTY, 3 telephone and 1 orderwire channels. (Some versions have 18 channels.)
- AN/VRC-12 is a family of vehicular mounted short-range, fixed or portable sets. The family includes VRC-12, -43, -44, -45, -46, -47, -48 and -49. Also in the family are GRC125, -160 and MRC-109, -110.

3.3 UHF SYSTEMS

The UHF radios are more limited in use in the urban environment with the primary function of air-to-ground and ground-to-air use by forward air controllers and helicopter support personnel. Absorption/penetration losses limit the use of UHF in built-up areas. Principal UHF systems are described below.

- AN/MRC-138/UHF is similar to MRC-87A providing two-way secure communications for long distance, point-to-point and ground-to-air. The MRC-138 replaces the AN/MRC-83A, AN/MRC-123 and the AN/MRC-87A.
- AN/GRC-171A(V)2 for voice and data, between ground and aircraft, has 7000 channels with both AM and FM, both narrowband and wideband.
- AN/PRC-75A is a hand-held radio with short-range for FAC use and general ground-to-air. It replaces PRC-41 in manpack configuration. The PRC-75A is being replaced by the UHF version of AN/PRC-113.
- AN/GRC-135A is a self-contained transceiver, at fixed locations, similar to GRC-112.
- AN/GRC-112 is used for ground-to-air, from fixed locations, capable of handling voice or FSK in simplex or duplex modes.
- AN/GRC-134 is a self-contained, ground-to-air transceiver.

3.4 SHF SYSTEMS

Only useful in LOS and troposcatter modes, the 4.4 to 5.0 GHz frequency range is limited in usefulness in the urban environment. The SHF system consists of:

- AN/GRC-201 transceiver for voice and data at 32 Kbps data rate. The GRC-201 is a modified TRC-97. TCC-72 (MOD) telephone terminal can be used with GRC-201 for secure multiplexing. To satisfy multichannel requirements, this radio may have to be used in the urban area; it is evident careful siting of the radios will be necessary to obtain line-of-sight paths.

SECTION 4

OPERATOR TECHNIQUES FOR URBAN OPERATIONS

What To Do About The Problem

The first operator technique begins prior to arriving in the urban area. It consists of accumulating information about the local building construction types, street layout, utility systems and indigenous communications systems. Foreknowledge of native frequency utilization for radio, television, emergency systems, taxi cabs, paging devices and similar signal transmission systems will be necessary if available communications systems are to be used or not interfered with. This is particularly true for peacekeeping assignments where disruption of urban indigenous commerce and lifestyle are to be minimized.

4.1 FREQUENCY SELECTION

If radios are designated for specific functions and frequency assignments have been made in the Communications Operation Instruction (COI) for use in the urban environment, there is limited flexibility for frequency selection. Where frequency bands are assigned for tuneable radio sets, adjustments across the band are usually possible. Frequency selection can be made in three ways:

- Selection of radio type (band type)
- Frequency tuning within a band
- Selection of fixed frequencies on a radio set within a band

Urban Environment Considerations

Figure 4-1 provides a decision tree in the form of a simple flow diagram. It considers transmitter antennas at three locations (inside building, on roof, in street) and two receiver antenna locations (inside building and in street). The choice of band and frequency within the band is based upon considerations of building structure sizes, whether antennas are located inside or outside buildings, and line-of-sight considerations for UHF radios.

Absorption and Penetration

If the receiver's antenna is located inside and close to the center of a large building, large signal losses occur due to absorption. These can be

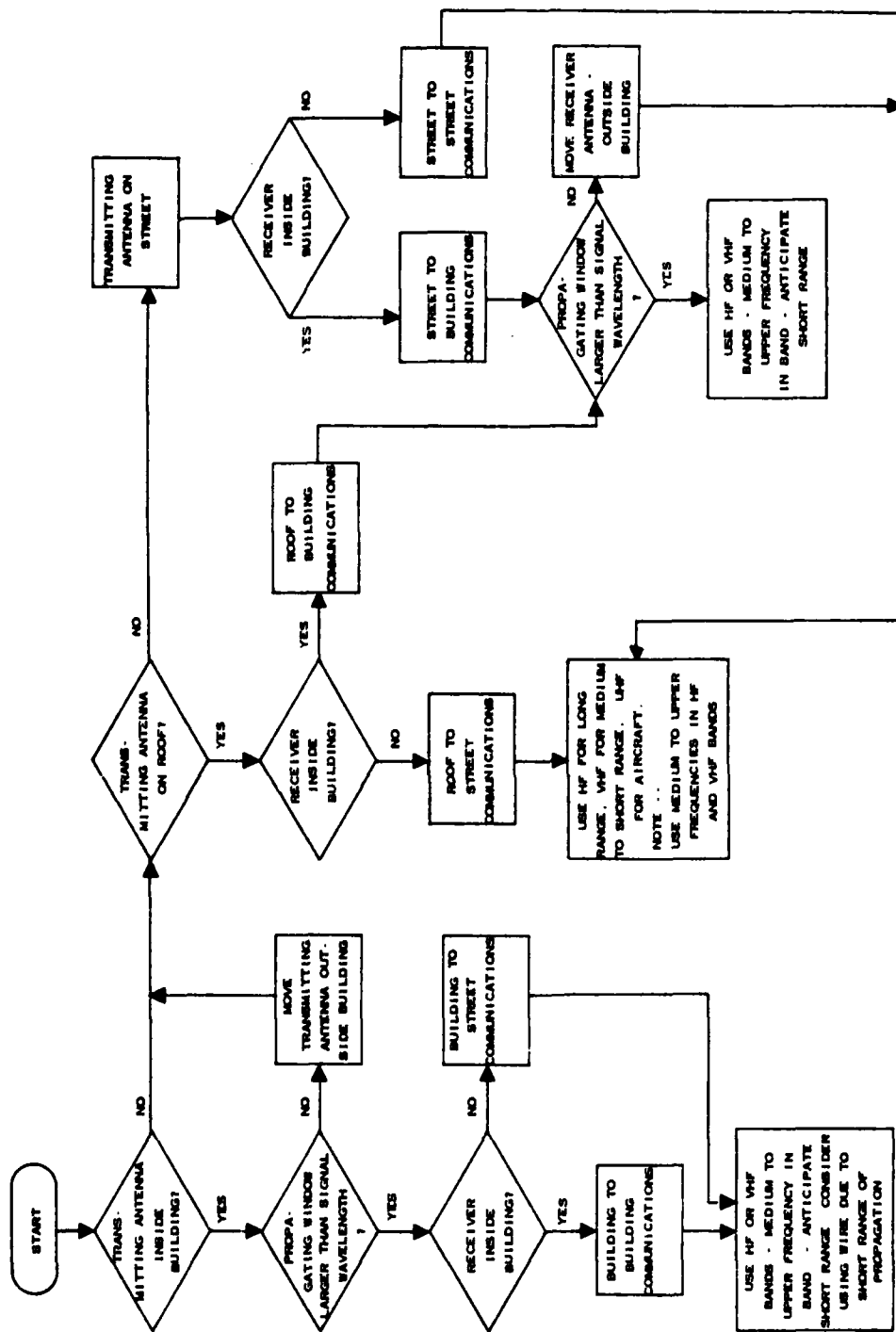


Figure 4-1. Frequency Selection Flow Diagram

reduced by moving the receiving antenna to a higher floor to obtain line-of-sight or moving closer to the building exterior on the side facing the transmitter. This phenomenon is frequency dependent. Lower frequencies penetrate better than higher; however, there is a threshold frequency which is the optimum building penetration frequency for each particular building. As frequency decreases below the threshold, penetration losses increase and as frequency increases above the threshold the penetration losses also increase.

Frequency Changes

The COI may designate specific times for frequency changes, or equipment operators may agree on a prearranged schedule for frequency changes within assigned bands. This not only adds to cover and deception operations, but through careful planning, it can optimize circuit reliability.

Multipath Enhancement

Multipath effects are usually thought to be a degraded signal transmission phenomenon; however, there are multipath enhanced frequencies just as there are multipath degraded frequencies. Once radios are in place, the most favorable frequencies can be determined only by experimentation. If the antennas are mobile, trial and error will be required to locate the most favorable antenna locations.

Performance Variability

Measurements have been made to demonstrate differences in performance associated with changes in frequency. A plot of error rate versus frequency is shown in figure 4-2. These data were obtained from a test using the PRC-77 radio transmitting to the receiver site over a distance of approximately 1 km. The data indicate a wide variability in performance for the frequencies used in the test (Note: The lines drawn on the figure do not imply linear behavior between the measured points, but are presented to illustrate the large changes in bit error rate). Such differences in performance can be attributed to several factors, such as antenna performance at different frequencies, antenna patterns, near proximity of obstacles, multipath effects, variable refraction, and noise characteristics at the different frequencies. The presence of these combined effects in the urban environment guarantees that this type of variability will be faced by any urban communication systems. These and other tests have shown 10 to 20dB variations over only 2 or 3 MHz of frequency

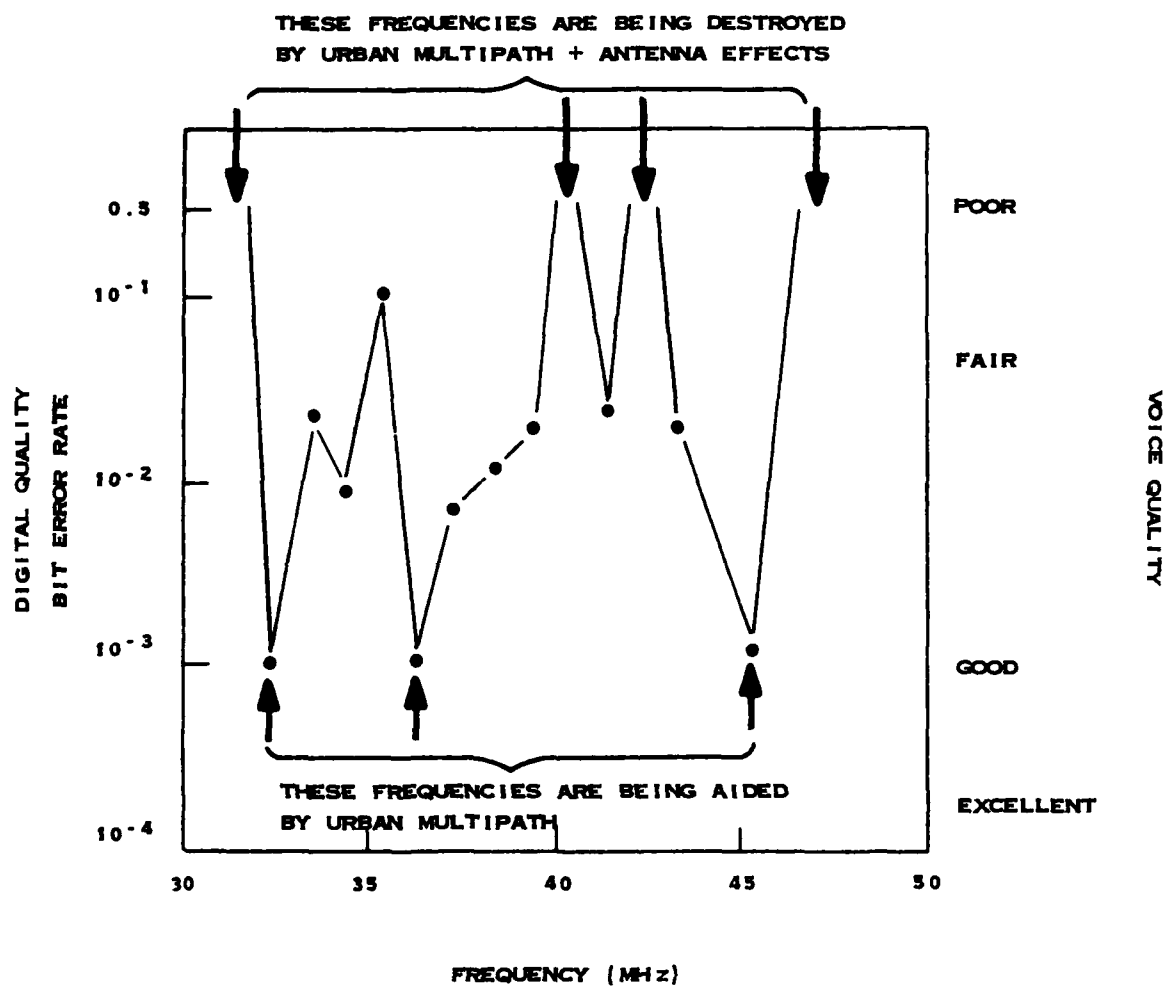


Figure 4-2. Example of Combined Effect of Antenna Impedance and Building Proximity Effects on a VHF Circuit

change. If poor communications exist, changing frequencies can often lead to quick improvement. Coordination procedures for change need to be carefully selected.

Range Limitations

Range of transmission will vary depending upon the radio selected, the antenna selected and the physical environment in which it is operated. Transmitter power is another important consideration, since most manpack radios have low output power. In general, when the transmitter and receiver are both in relatively open areas, but separated by tall buildings, range may increase by a factor of two. Conversely, if both transmitter and receiver are in narrow streets and surrounded by tall buildings, range coverage may be reduced by a factor of two (especially at VHF and UHF). This range reduction may not be circumvented by using HF radios if small, inefficient antennas are attached. The HF band is more appropriate for fixed, point-to-point communications, especially where larger efficient antenna systems are available.

4.2 EQUIPMENT PLACEMENT

Antenna Diversity

Proper location of equipment and selection of the best equipment for the particular situation are critical to effective urban communications. Using two colocated receiving antennas provides diversity reception by combining separately received fading signals into one less fading signal. Polarization diversity is possible by using a whip and a loop antenna with the same receiver. Space diversity can be achieved using two whip antennas separated by at least a half-wavelength.

Antenna Siting

The most favorable location for transmitting and receiving antennas is within line-of-sight of each other and away from walls, bridges and other massive structures. Nearby structures can change antenna impedance and reduce antenna efficiency. Moving a receiving antenna from a sidewalk to the center of the street has doubled signal quality in some cases. City street patterns should be considered when siting antennas, particularly when antennas are at street level or on the lower floors of multi-story buildings. Street patterns are usually a combination of common types. Street intersections are the optimum antenna locations if only street level elevation is available.

Antenna Grounding

Siting must also consider availability of grounding mechanism for the antenna. This is particularly true for HF antennas where high power levels exist. Proper grounding will improve signal strength but is difficult to achieve in tactical situations. The advantage gained in improved range by locating antennas above the third floor of built-up areas may be forfeited by improper grounding. Use of water pipes and metal elevator shaft parts can provide adequate grounding.

Signal Reflection

It is sometimes possible to use a metal-walled building or high metal fence to reflect a signal in the direction of the receiving antenna. For frequencies between 30-50 MHz, place the antenna two meters (6.5 feet) away. At higher frequencies between 50-88 MHz, place it no more than one meter (3.2 feet) away. If the antenna is further away than suggested, the signal may be reduced. When initially establishing the link, move the antenna a foot or so to obtain the strongest signals. Repeat this process when the frequency is changed.

Finding Best Reception

The location of the antenna relative to the surroundings can have a profound effect on the quality of communication. The communicator must be aware of the interactions of his antenna and the surrounding environment to capitalize on desirable features and avoid those which degrade signal quality. Sometimes a relatively small change in the position or orientation of the antenna can make the difference between unacceptable and acceptable communications. A general rule of thumb to follow with portable equipment, particularly hand-held and vehicle mounted equipment, is to move it while receiving and fix your location at the point of best reception. However, haphazardly moving the antenna may not always work. Study the characteristics of the surroundings to try to determine the cause of the problem before moving in a direction believed to provide better reception.

Near Proximity Effects

The characteristics of an antenna and the environment can be defined in terms of two distinctly different regions: near proximity and far field. Near proximity refers to the area in the immediate vicinity of the antenna, typically within one or two wavelengths away. Far field refers to the region beyond this boundary.

Within the near proximity region, all nearby conducting objects are effectively a part of the antenna, whether by design or accident. When an antenna is physically located near to another object, the antenna pattern becomes distorted. In addition, RF transmitted energy may be coupled into the object rather than be efficiently radiated. This scenario, unfortunately, describes just about every tactical urban communications path. Examples of near proximity effects are commonplace and include the integral antenna on a hand-held or backpack transceiver and a jeep-mounted whip. In the first example, the operator becomes part of the antenna and body orientation with respect to the transceiver determines the direction of maximum signal strength (see figure 4-3). In the example of the jeep, the vehicle contributes to the antenna radiation pattern but the pattern of radiation is less predictable. The following three figures show simple examples of a VHF (MRC-109) with a whip antenna mounted on a jeep. The proximity of the jeep and a partially conducting ground both distort the radiation pattern. The position of the jeep and antenna are at the center of figures 4-4 and 4-5. Large deviations from uniform, concentric radiation patterns are obvious on figure 4-4. These are due to ground interactions. The deviations would even be more distorted if urban structures were present in addition to the always present ground and jeep-body effects. Figure 4-6 displays a typical vertical radiation pattern at 30 MHz. Note the non-uniform pattern caused by the jeep body. Keep in mind that if the frequency were changed, the wavelength/phase relationships between the antenna, the jeep and the ground would all change: the result would be a completely different radiation pattern - though still distorted from uniform.

Wavelength and Object Size

Examples of sources of unplanned proximity effects include nearby metal objects such as wire fences, door and window frames, structural beams and metal composites in the building walls, towers, storage drums, etc. Relative to the size of the wavelength, smaller objects can produce fringing effects; large objects can act as reflectors; and objects of comparable size to the wavelength can act as radiating elements. In general, move away from small objects. If a large reflector is nearby, orient the antenna in front of the reflector in the direction needed to communicate (see figure 4-7). The most critical problem occurs when the objects are of comparable size to the wavelength. In this case, any small change in distance will have a major effect on antenna efficiency (see figure 4-8).

Your body can act as an antenna and affect the quality of the radio signal - particularly backpack and hand-held VHF sets with short antennas. The affect of the body on signal strength depends on: frequency, antenna length, and the position of antenna or set relative to the operator's body.

BACK PACK SETS (AN/PRC-77)

DIRECTION OF BEST COMMUNICATIONS

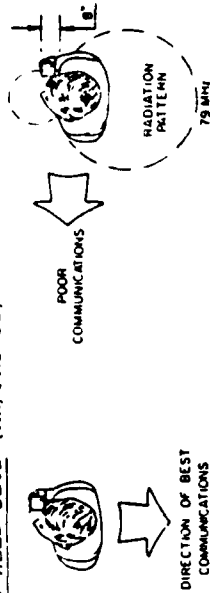


- Maximum radiation (best performance) is to the front when the set is on the operator's back with a 3-foot whip antenna - try facing the direction of distant communications. This works best at higher frequencies (> 50MHz).

- When the set is on the ground and the operator is very close to the set, maximum radiation will probably be in the direction through the operator's body. If the operator is a couple of feet away, other pattern characteristics might be found at high frequencies such as the operator acting as a reflector and either improving or interfering with the signal.

- Coverage with a 10-foot antenna will be little affected by the operator unless standing close to the radio set on the ground.

HAND HELD SETS (AN/PRC-68)



- This antenna is much smaller than AN/PRC-77 and the operator's body affects directional characteristics to a greater extent, particularly with the antenna in a lowered position.
- This radio will normally be in the front jacket pocket and best performance is then over the back.
- The higher frequencies are strongly affected with the antenna in lowered position.
- Holding the radio in hand a few inches away from the body will modify the radiation pattern and can substantially lower performance to the sides at the higher frequencies. The directional characteristics of the antenna-body combination can be used to some advantage in reducing interference arriving from directions other than that of the signal. Trial and error is necessary to make this judgment.

Ref: OH 10-3

Figure 4-3. General Orientation of Hand Held and Back Pack Sets

75 MHz

Elevation angle = 0°
5 dB per 'ring'

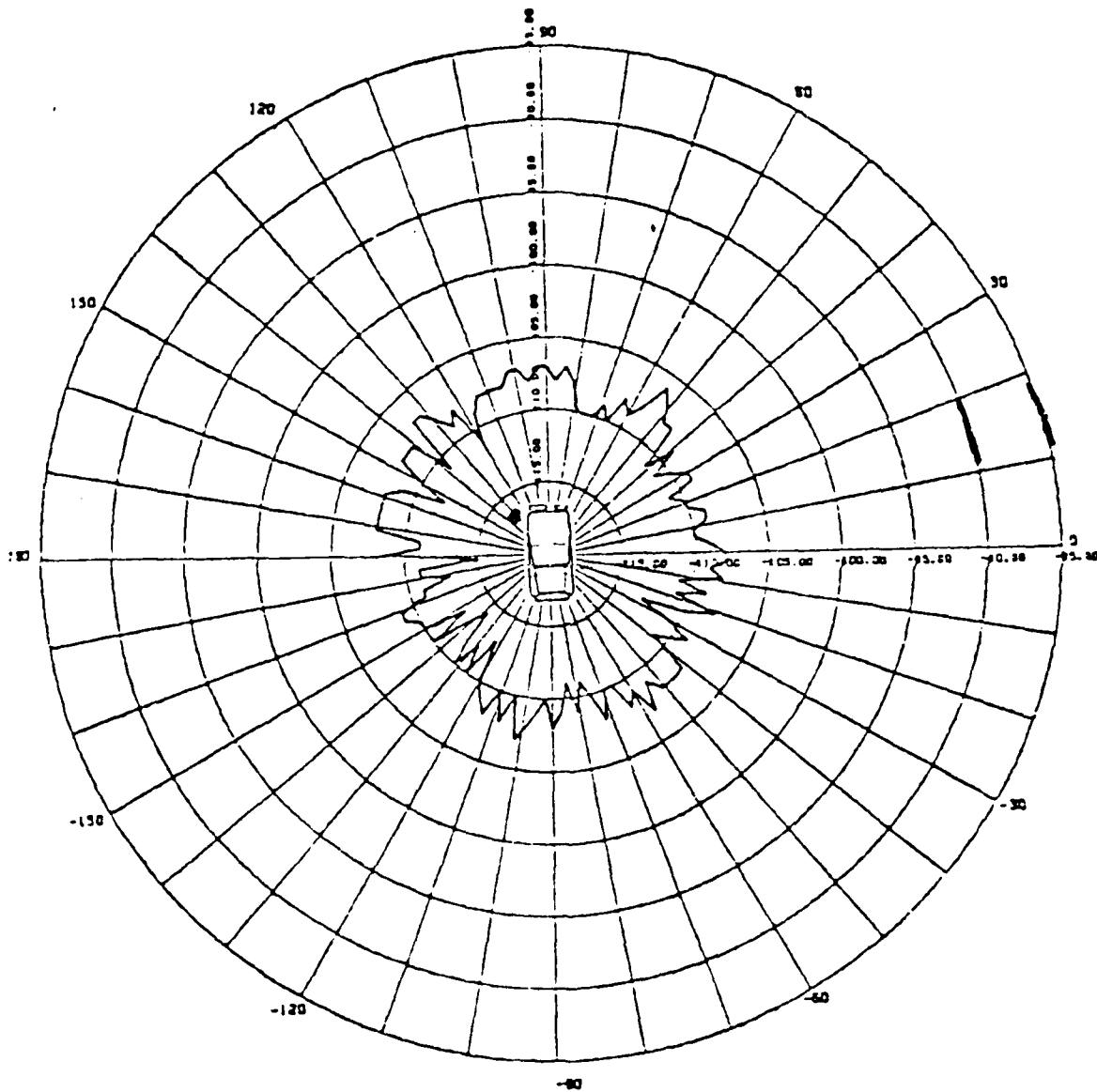


Figure 4-4. MRC-109/110 Horizontal Antenna Radiation Pattern at Ground Level

75 MHZ

Elevation angle = 10°
5 dB per 'ring'

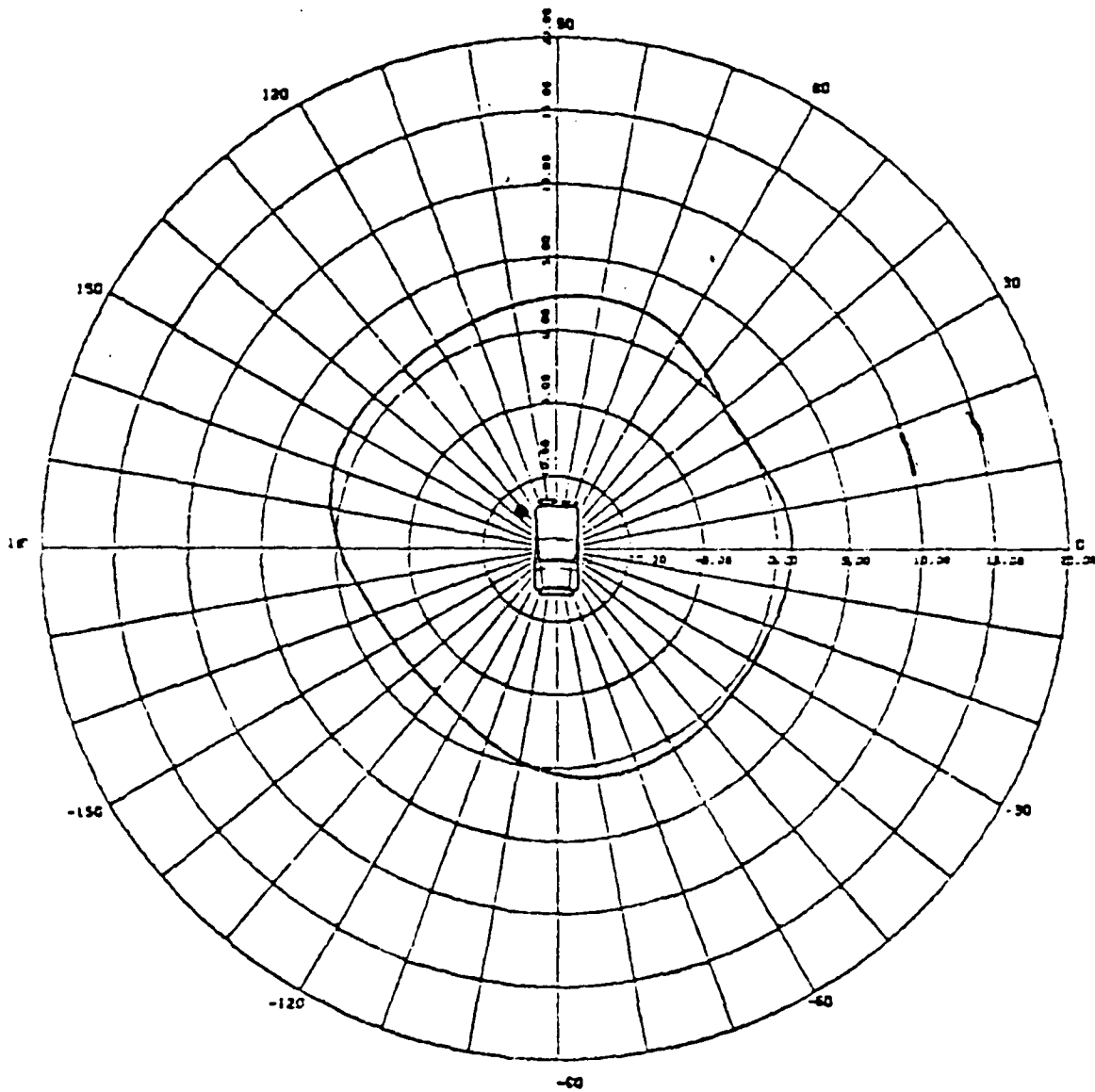


Figure 4-5. MRC-109/110 Horizontal Antenna Radiation Pattern at 10° Elevation Angle

30 MHz

Vertical radiation pattern
along major axis of jeep

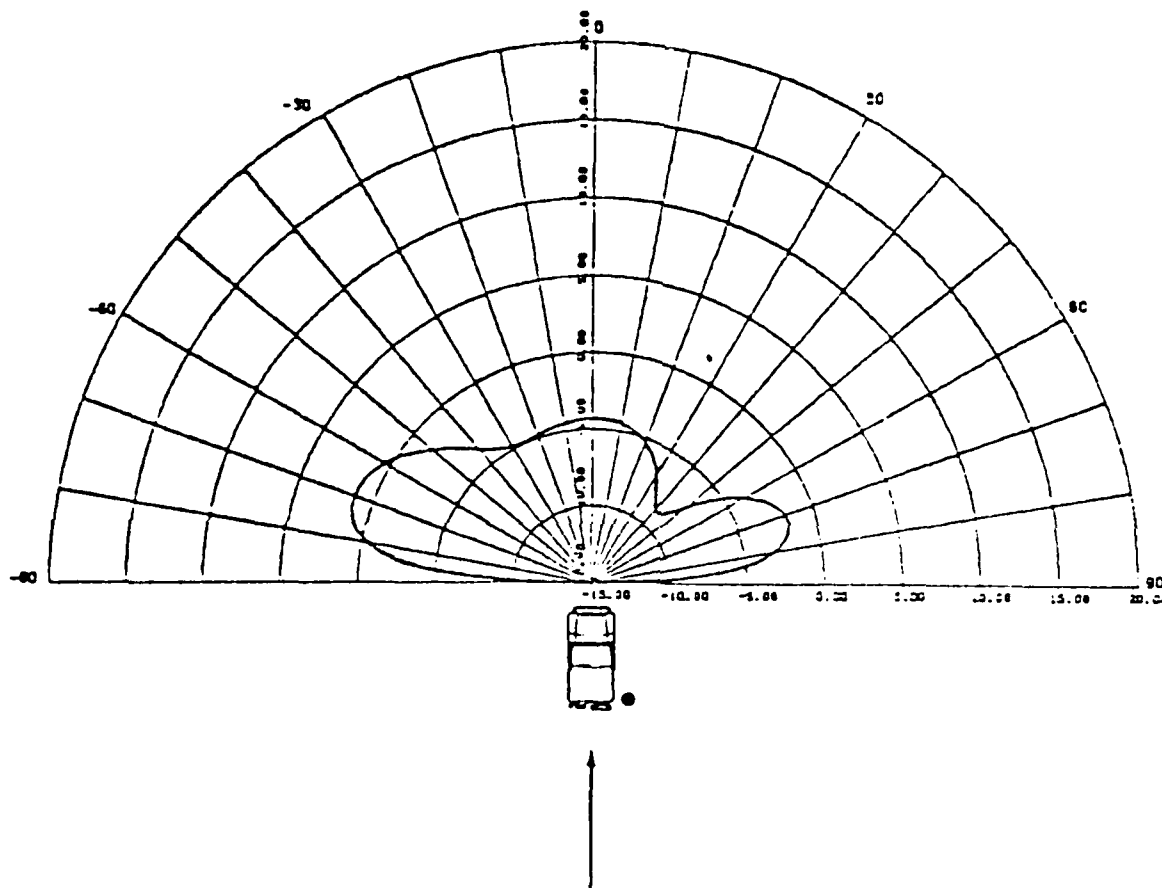


Figure 4-6. MRC-109/110 Vertical Antenna Radiation Pattern

If near a metal-walled building or high metal fence, site the antenna close by to reflect a directive pattern away from the wall or fence in the direction you wish to communicate. For frequencies between 30 - 50 MHz, place the antenna approximately 2 meters (6.5 feet) away; between 50 - 88 MHz, place it no more than 1 meter (3.2 feet) away. If any farther away than this, communications may be reduced. When first setting up the equipment, vary the distance a foot or so in each direction while receiving to find the position where the signal is the strongest. If you change frequencies later, the optimum position will have to be redetermined at that time by the same method. Also, if the transmitter is moved, you will probably need to move the receiving antenna to find the best location to receive the reflected signal.

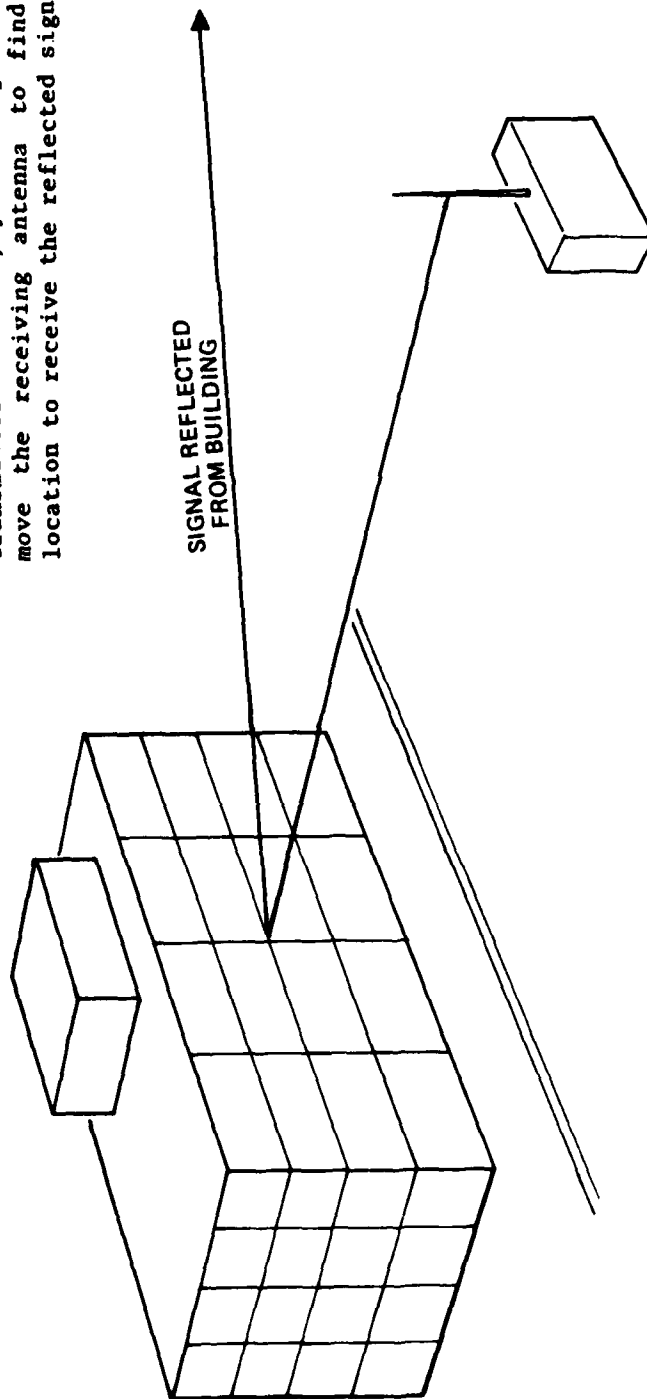
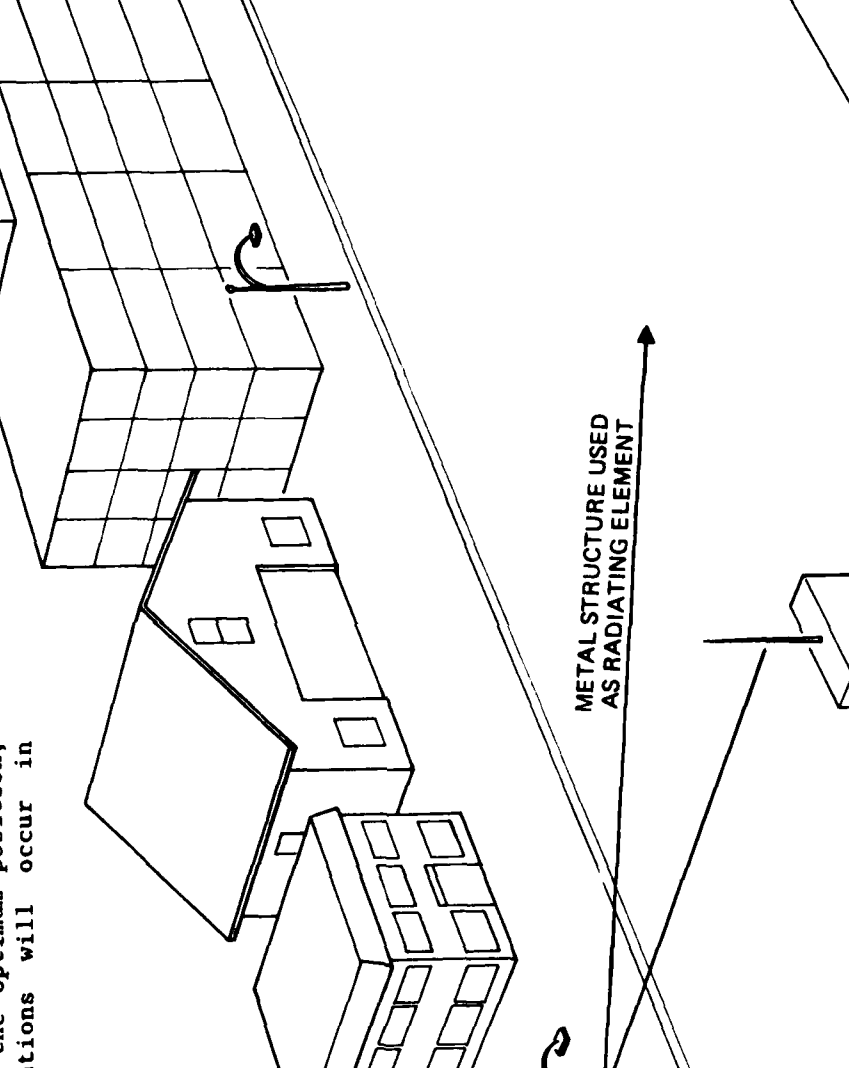


Figure 4-7. Using Reflections from Nearby Buildings to Advantage

sequence radiation pattern. The loss of signal strength rather than loss of signal strength when the antenna is not in the optimum position. Use this method only when the antenna is not in the optimum position; fluctuations will occur in the signal strength.



The diagram shows a perspective view of a building complex. A large rectangular building with a grid pattern on its side is on the left. To its right is a smaller building with a gabled roof and several windows. Further right is another building with a grid pattern on its side. A curved arrow points from the top of the large grid building towards the smaller building. A long arrow points from the bottom right towards the top left, labeled "METAL STRUCTURE USED AS RADIATING ELEMENT". A small rectangular box is connected to this arrow by a line. A curved arrow points from the bottom right towards the top left, labeled "METAL STRUCTURE USED AS RADIATING ELEMENT".

Figure 4-8. Using Objects of Comparable Size as Radiating Elements

4.3 OTHER TECHNIQUES

Wire Reel Antenna

The reel antenna is a significant, simple addition toward improving antenna efficiency by adding antenna length and placing the radiating surface at or outside of building surfaces. With a small set of additional gear and readily available items in the local environment, it may be possible to exploit selected components in the immediate area of the transmitter site by using them as transmit/receive elements. The wire reel can be used to quickly reconfigure the transmitter sites and capitalize on the surrounding environment, such that obstacles aid in communication.

A reel antenna (nomenclature AT-984A/G) consists of a reel of wire with a spade lug at the free end of the wire (see figures 4-9 and 4-10). The unit is designed for the spade lug to be inserted under the base of the PRC-25 or PRC-77 whip with the whip removed and the base tightened down to hold the lug in place. The wire is then unrolled to a convenient length and the reel end thrown over an appropriate object (to form an elevated wire antenna) or wrapped around a portion of a conducting object which will be used as a radiator. From a multistory building the antenna wire can be hung out the window to achieve a vertical antenna. For optimal performance with a VHF transceiver, the wire leading from the transceiver to the radiating section should be approximately parallel to and 4 feet above the ground.

The wire reel is most commonly used with any low power VHF transceiver without undue concern for antenna mismatch. It may also be used for higher power transceivers in both the VHF and HF regions where coupling and impedance matching can be controlled, wither by built-in adjustments in the transceiver or via an external matching device. In outside areas, objects to be exploited as radiators include nearby towers, sides of buildings, fire escapes, trees, large vehicles, etc. Inside a building, the wire can be wrapped around a metal window frame, portions of air ducts or elevator shafts, water heaters or coolers, etc. The radio operator should experiment with different objects, different lengths of wire, and different means of coupling (e.g., good electrical connection, inductive loops, etc.) until optimum communication can be achieved.

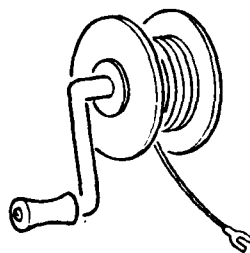


Figure 4-9. Illustration of Reel Antenna

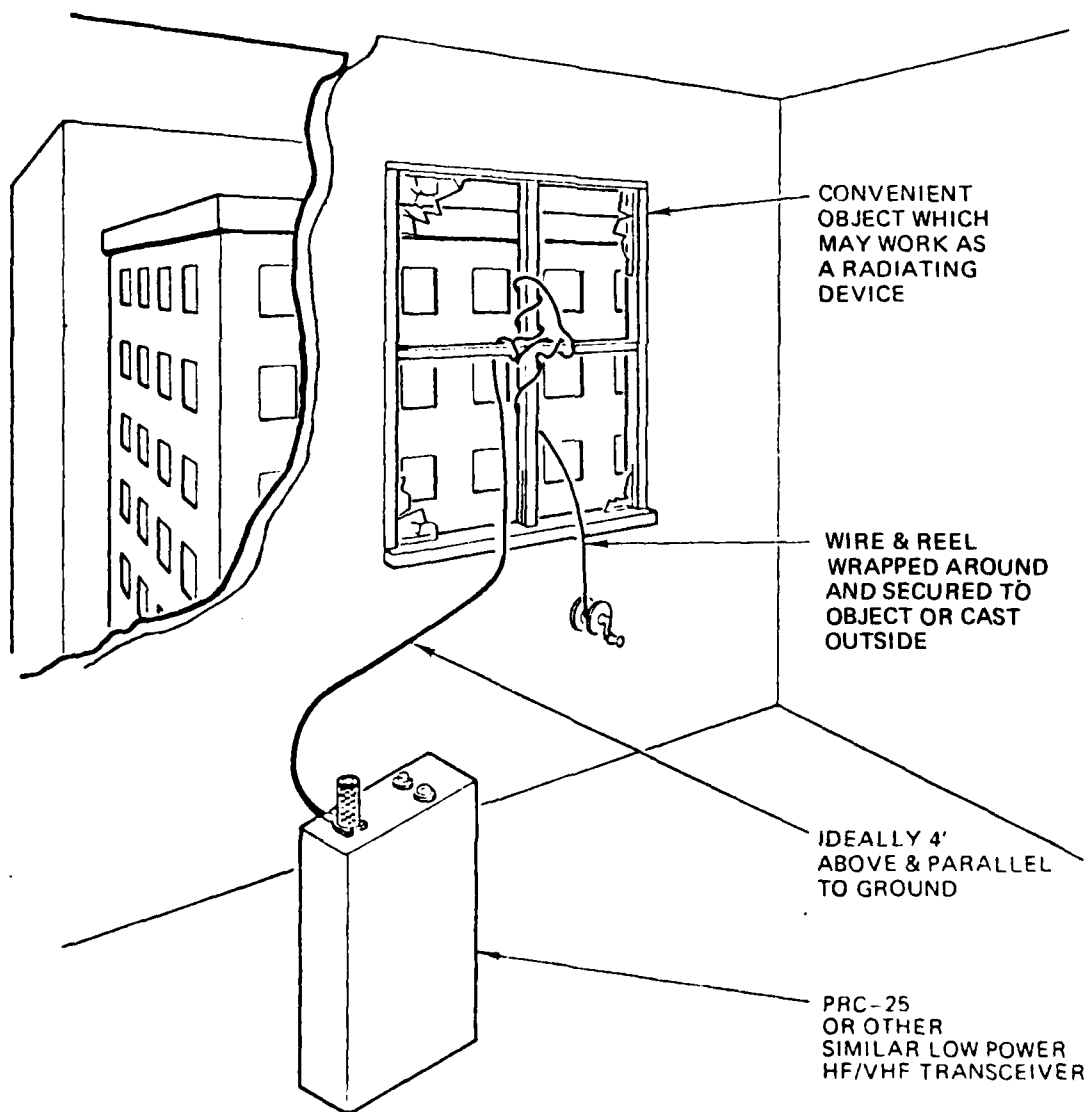


Figure 4-10. Typical Application of Reel Antenna

Urban terrain usually contains an abundance of utility poles and to a lesser extent underground passages such as sewer systems, subways and utility tunnels. Where possible, these assets should be exploited by installing wire conductors on the poles or through the passages. When communications facilities are sited, ease of access to these assets should be included in the planning. Wire communications not only enhance security, but in the urban environment, usually improve quality of communications as well.

Inter-Building Technique

If communications are to be established within a building, proximity of stairwells and elevator shafts should be incorporated into the siting of the equipment. This facilitates stringing wire conductors (if available) or using the vertical shaft for signal transmission by reducing the intervening building floors which act to absorb signals. Within a building, and in some instances, within an urban area, commercial power distribution wires may be used. With suitable isolation, these power distribution networks can be used for short and perhaps intermediate range RF energy distribution. The radio RF output can be fed directly into existing power lines through a filter that prevents low frequency power line voltages from damaging the radio. This power line technique is sometimes used to distribute broadcast band (550-1600 kHz) AM signals throughout large buildings such as dormitories and hotels. Signal coverage depends heavily on the local power system design and the local power load.

Power Line Limitations

Power distribution systems that have numerous voltage step-up/step-down transformers, circuit breakers, isolation transformers and metal-shielded conduit are relatively poor for RF distribution. Such systems are typical of the relatively stringent building codes and electrical construction codes of North America. Under these conditions 1 to 5 watt RF transmitters coupled and AC isolated from power lines can generally provide coverage throughout buildings of up to perhaps 10 stories, and also to surrounding areas, if incorporated in a common area power system. Power system designs of the Middle East, Africa, etc., having fewer components, conduit, and shielding would generally be better for use as carriers of RF power.

Resistive loading and losses

RF power over a power distribution system also depends on the AC load on the system at the time. Electrical appliances that are primarily resistive, such as electric heaters, toasters, ovens, etc., will also consume the RF power coupled on the line. To a lesser extent, connected light bulbs will absorb, rather than transfer the RF energy present on the lines. Thus, in general, at nighttime there will be more resistive losses in the line than during daytime. A low power RF system that could cover one or two 10 story buildings during daytime might be limited to less than one building during early evening hours due to resistive losses in the loads that are switched on in the evening. Resistive loading and power consumption will be lower in less developed regions of the world than in advanced countries. Urban area coverage can be as little as a single major building or may possibly extend several blocks.

RF coupling

When existing radios and power systems are used for power-line coupling the only additional piece of equipment required is a high pass filter/isolator with the proper connectors to plug into the radio and power system (as shown in figure 4-11). HF radios tuned to the lower end of the band are likely to provide maximum area coverage.

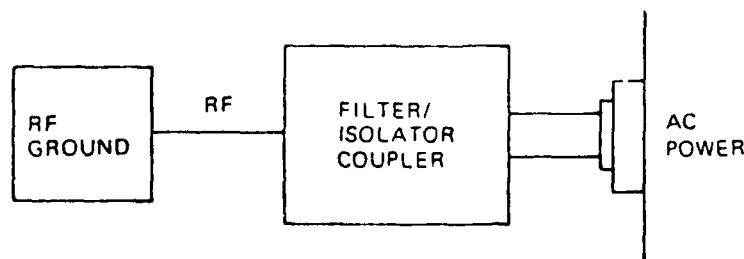


Figure 4-11. Power-Line Coupling

4.4 INTERFERENCE

Interference is the result of the disturbance of signals between transmitter and receiver or the hindrance of signals by extraneous power sources. Multipath is the principal reason for signal disturbance while natural and man-made noise, including other radio sets, can introduce interference in the urban environment. Moving the receiving antenna a distance of one-quarter wavelength or greater may reduce or eliminate multipath from fixed-location reflectors. If the reflector is a reoccurring moving object such as a train, airplanes or automobiles, complete relocation may be necessary or switch receiving antennas to a directional antenna.

When signals are disturbed by man-made sources such as ignition systems, diathermy machines, electric trolleys, power generators and transmission systems, the primary means to reduce interference is to isolate the receiver from the source of interference. This can be accomplished by siting the receiving antenna in an area remote to the interference source or moving behind an obstacle which will provide a shield, such as a large building or metal fence.

4.5 EQUIPMENT CONDITION

Proper first echelon maintenance will assist in keeping communications equipment in serviceable and top-notch working order. In the urban environment special care must be exercised to maintain proper grounding of equipment and to ensure that antenna cables are the shortest length possible and shielded whenever necessary. Power lines and telephone lines should be as short as possible and lying on the ground/floor when in the vicinity of antennas. Remote control equipment must be regularly checked by maintenance personnel to ensure optimum performance.

SECTION 5

IMPROVED DEPLOYMENT

How To Put It Into Action

5.1 FREQUENCY USAGE/MANAGEMENT

During the planning phase for an amphibious assault operation in an urban complex, the frequency manager must conduct a detailed study of the electromagnetic characteristics of the objective area. To do this the manager should obtain information concerning the urban structures and construction materials used in the area, the electromagnetic background noise, frequencies expected to be used by civilian radio and television, and the availability of civilian communication facilities. Blocks of frequencies in the VHF range should be allocated to the urban units using organic radios. They will be incorporated in the daily frequency and call signs plan for assignment to combat and combat support elements. HF frequencies will be assigned to supporting arms control agencies and elements of reconnaissance and surveillance.

In the multipath urban environment, large numbers of frequencies should be made available so that multipath-enhanced frequencies can be found. Even with careful frequency usage and management practices, interference may sometimes occur. Interference can result when two separate transmitters attempt to use the same frequency or even when different frequencies are used. If interference occurs, the source should be identified. If it appears that the interference is caused by the enemy, a Meaconing, Intrusion, Jamming and Interference (MIJI) report must be made to headquarters. If it appears to be from a friendly transmitter, an identification of the source should be made and a MIJI report may be required. The interfering operator should try to lower the transmitter power as long as it does not degrade his own circuit.

5.2 ANTENNA IMPROVEMENTS

Antenna Placement

Mutual interference can often be reduced by a combination of careful frequency selection and careful antenna placement. As much distance as possible should be put between the interfering signal's antenna and your own. Shielding by moving to the opposite side of a building or moving to a higher or

lower floor within a building can provide valuable separation. If the equipment is mobile, move to a different block or street pattern to avoid the offending circuit. Changing to a directional antenna can also be a valuable way to enhance reception.

Antenna Detection

When more than one antenna is to be sited in a section of the urban area, careful management of antenna emplacement is required to prevent enemy recognition. Consideration of total antenna requirements including power, emission, pattern and lobes are necessary to minimize mutual interference and prevent establishment of an "antenna farm". It is necessary to be ready to take advantage of natural camouflage and to reduce visual detection of the radio site.

Antenna Height

Height of the antenna is possibly the single most important factor in urban communications. Because the received signal level can be increased by as much as 6 dB per octave of antenna height, the operator should locate the antenna as high as possible.

Antenna Size

Extending the size of an antenna can sometimes be accomplished inside a building by touching the antenna to an air duct or a standpipe. Elevator shafts can also provide an enhanced path to the outside of a building.

Antenna Polarization

Existing antennas are designed for vertical polarization; therefore, the antennas should be kept reasonably vertical. A loss of signal results if the antenna is too near the human body or is lying on the ground. Use maximum possible antenna extension and place it outside metal buildings or thick concrete buildings with small windows.

Space Diversity

Space diversity can be implemented by using multiple antennas with a minimum separation of $\frac{1}{2}$ wavelength. Thus, the required minimum separation is 2.5 meters at 60 MHz and 0.25 meters at 600 MHz. The two ends of a jeep can provide space diversity for 60 MHz signal. At 600 MHz, space diversity of a hand-held radio becomes feasible since two antennas need to be a minimum of 10 inches apart.

Vegetation Problems

Be aware of the shadowing effect of terrain and the loss due to propagation through trees. If operating in a wooded area, such as a park or playground, try to locate the antenna at the edge of the woods or elevate the antenna above the tree level.

5.3 RELAYS AND REMOTE TRANSMISSION

The use of line-of-sight relay facilities at critical building locations can improve communications across an urban area. Rooftops provide the most favorable location for relay equipment; although, roof loading capacity must be considered if heavy equipment is to be used. Relay equipment adds to transportation and maintenance requirements; therefore, installation of land-lines, although more time consuming initially, may be more reliable for extended periods of operation in one urban area, such as peace-keeping duties.

Remote transmission equipment has two potential advantages:

- Concealment of the communications center location
- Advantage of hilltop or rooftop height for possible line-of-sight circuit installation.

Remote transmission and receiving is feasible and anticipated when communications centers are located in underground facilities or on street-level inside large buildings. The VRC-83 is a vehicular mounted, VHF radio set which may be operated from remote locations. The GRC-171A is a UHF radio which can be remotely controlled and is remotely tunable for communications with aircraft. When the TRC-170 SHF troposcatter radio becomes available, it will have both remote subscriber access and subscriber access at relay points.

SECTION 6

FUTURE TECHNIQUES/TECHNOLOGIES

Look What's Coming Down The Pike

6.1 PACKET RADIO

New concepts for digital ground mobile radio communications are being developed. Packet radio is a centralized system so that with properly located network nodes, an effective urban area communications system will be available.

The packet radio is a multiplex technique using a predetermined network protocol. Transmissions are accomplished in packets of data, typically containing approximately 2,000 bits of information. Since messages from one point in the network to another may involve one or more relays, a portion of the information in each packet is reserved for addresses (destination and source). Spread spectrum techniques can readily be applied to packet radios to reduce multipath degradation to acceptable levels. Practical limitations dictate carrier frequencies that extend from upper VHF band (300 MHz) to the lower SHF band (30 GHz). Probably 1710 - 1850 MHz will be used with a bandwidth up to 140 MHz in a spread spectrum mode. Packet radios are a natural extension of the existing point-to-point land line packet communications systems.

6.2 MILLIMETER WAVE RADIO

Millimeter wave communications systems use the 10 - 100 GHz range. Primarily a line-of-sight communications band, there are indications that reflection coefficients off smooth structures are high enough to permit limited non-line-of-sight performance. Proven tactical communications between two ground stations require a direct line-of-sight path between the stations or a path involving one or more relays. Power requirements are small and can be met with lightweight solid state devices. Spread spectrum can be used to minimize multipath induced distortion; however, the reduction of multipath effects is not as significant in millimeter wavelength as for the longer wavelength bands. Attenuation effects from rainfall can be mitigated by space diversity of antennas and by polarization diversity.

6.3 ULTRA-VIOLET RADIO

Ultra-violet (UV) radio systems will have a primary place in urban and suburban communications. Principle advantages of UV will be the construction of non-line-of-sight networks due to atmospheric scattering and good security of signals due to almost complete atmospheric absorption beyond approximately 2 km. The portion of the electromagnetic spectrum to be used for UV communications is essentially noise free at both day and nighttime. Atmospheric scattering allows UV to go around building corners, over the top of two and three story buildings and be detected up to 1 km from the source. Inside buildings it has been demonstrated to go around several corners and down long hallways.

6.4 CELLULAR RADIO

Cellular radio is an approach to mobile communications based on the concept of "close-space, frequency re-use". Within a geographic area, such as a city, smaller areas, known as discrete cells, are defined. Each discrete cell in the urban area is assigned a portion of the UHF band and a certain number of channels. Since low-power transmission is used, the same frequencies can be assigned to other, separate discrete cells in the urban area. To minimize interference, the same frequencies are not assigned to adjacent cells. A central switching station assigns frequencies, routes messages and ensures that the intended recipient has acknowledged the message. If the location of the destination unit is not known, the message may be sent to several discrete cells.

SECTION 7

SUMMARY

Here's What We Talked About

- Know characteristics of the urban area before arriving there.
- Locate VHF and UHF radios in positions that will maximize the available line-of-sight.
- Be aware that small changes in frequency or antenna position can yield large improvements in signal quality.
- Use retransmission facilities to provide line-of-sight by placing them on top of tall structures or nearby terrain features.
- Maximize the use of remote radios to obtain line-of-sight and to reduce the effectiveness of enemy direction finding and destructive fires.
- Place VHF radios as close as possible to the vertical alignment of steel girders in a structure.
- Maximize use of radios that are least dependent on line-of-sight, such as HF systems.
- Maximize the use of other means of communications, such as wire, messengers, and visual and aural signals.
- Use metal parts of buildings to establish a good ground.
- Keep antennas away from massive structures by favoring the center of streets over sidewalk or building interior placement.
- Use linear street patterns for establishing line-of-sight equipment locations.
- Try space diversity using two antennas located $\frac{1}{2}$ wavelength apart.
- Use wire reel to create antenna outside building surfaces.

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